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THE TICKS OF BRITISH COLUMBIA[1]

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GENERAL

In the present paper, data on the ticks occurring in the province of British Columbia are summarized. No detailed descriptions are given, since a more extensive paper is under preparation dealing with the ticks of Canada, which will be of a more technical nature, and which will include illustrations and detailed descriptions of Canadian ticks in their various stages. The present paper is more of an annotated check list of the Ixodoidea of British Columbia.

In connection with a tick survey[2] of the province, being conducted by the Kamloops laboratory, literally thousands of rodents, game and domestic animals and many birds have been examined. As a result there has been accumulated an extensive collection of tick specimens which provide a large part of the material for this paper. Through the courtesy of Professor G. J. Spencer and Dr. J. H. McDunnough the tick collections of the University of British Columbia, and the Canadian National Collection of Insects, respectively, have been placed at our disposal and have proved of great value and interest. Thanks are also extended to various collectors and individuals who have supplied interesting specimens and data. It is out of the question to list all of these contributors, but special mention should be made of Mr. Kenneth Racey, who has been most helpful and Professor G. J. Spencer, who, in addition to material of his own collecting, has permitted examination of collections of the late Mr. R. A. Cummings. Mr. Bryan Williams, Commissioner of the B.C. Game Department, and Mr. F. Kermode, Curator of the Provincial Museum, have also supplied interesting specimens from grouse and other hosts.

Anyone interested in the ecto-parasite fauna of British Columbia will be familiar with the valuable pioneer work on ticks undertaken by Dr. Seymour Hadwen. It is a tribute to his thoroughness that we are able to add so

[1] For the past eight years one of the major projects at the Dominion Entomological Laboratory at Kamloops, B.C. has been a survey of the tick fauna of British Columbia. This project was inaugurated by the late Eric Hearle in 1928, and carried on by him until his untimely death in 1934. During this period Mr. Hearle had accumulated and worked over more than 3000 specimens, collected from a variety of hosts, ranging from shrews to grizzly bears, and including a variety of birds. Just prior to his death his preliminary report entitled *The Ticks of British Columbia* was read at the 1934 Annual Meeting of the B.C. Entomological Society. Owing to the author's death soon afterwards this paper was never published, and the manuscript has remained from that date awaiting minor revisions and a further scrutiny of some of the material. Since 1934 many additional data and specimens have accumulated at the Kamloops laboratory. Most of this new material has been worked over during the past two winters by Messrs. G. Allen Mail, J. D. Gregson, and G. P. Holland. The report as now presented remains largely in its original form, with the exception of minor revisions to the notes on tick-borne diseases, and further data on specimens examined by the present laboratory staff.
—A. GIBSON.

[2] Assistants at the Kamloops laboratory who have done much of the field work in this project include I. McT. Cowan, 1929; H. Mobley, 1930; the late R. T. Turner, 1931 and 1932; D. Cameron, 1933; T. K. Moilliet, 1931 to 1936, and J. D. Gregson, 1933 to date. Others who have helped are E. R. Buckell, A. A. Dennys, W. Downes, R. Glendenning and Ralph Hopping.

few new records for the province. Dr. Hadwen's published records appear mainly in the Reports of the Dominion Veterinary Director General, particularly those for 1912 and 1915, a few in the proceedings of the B.C. Entomological Society, and some important papers in *Parasitology*, these together forming the most important contribution yet made to our knowledge of Canadian ticks. Also of value is the more recent work of Dr. Bruce (2) which has added much to our knowledge of tick paralysis. The papers of Dr. J. L. Todd (22, 23, 24, 25 and 26) in the Canadian Medical Association Journal must not be overlooked in this connection. The only attempt at gathering together under one cover fairly complete data on Canadian ticks is that of Dr. C. G. Hewitt (13) whose paper, "A Contribution to a Knowledge of Canadian Ticks", was published by the Royal Society of Canada in 1915. It is indispensable to the student, but is not readily accessible, and, of course, in more than twenty years a great deal has been added to our knowledge of the distribution and disease-carrying propensities of ticks.

Buckell (3) in his paper dealing with ticks and parasites of game animals, indicates one phase of the importance of ticks, and shows why all who are sportsmen should be interested in tick investigations. Those who have given it close attention are satisfied that the periodic dying-out of rabbits is very possibly due to tularaemia, a tick-borne disease carried by the rabbit tick (*Haemaphysalis leporis-palustris* Packard) and other species. The various grouse and other ground game birds show a similar fluctuation from abundance to near extinction in some districts, and Greene and Shillinger (8) in Minnesota have shown that the same disease is often responsible. The habits and haunts of these game birds render them particularly liable to become infested by the rabbit tick, the bird tick (*H. cinnabarina* Koch.) and several other species. *Ixodes auritulus* Neumann is especially a culprit at the coast, and our tick survey has shown that a large proportion of birds in some districts in the interior may be infested with the first two mentioned species. Tick-infested grouse have been found dead in districts where the birds were markedly decreasing, and there seems little doubt but that tick-transmitted diseases are among the most important factors influencing the fluctuations from abundance to scarcity.

As to larger game, such as deer and moose, a number of examinations in the case of the former have shown heavy infestation with the winter tick *Dermacentor albipictus* Packard, in the winter and very early spring months, and *D. andersoni* Stiles is undoubtedly an important factor in March and April. Dr. Bruce has shown that heavy tick infestation has been followed by death in the case of mule deer; Bradshaw (1) reports the death of moose from ticks, and there is but little doubt that great losses are sometimes occasioned. Cases of deer having numerous pus pockets have been received by the Kamloops laboratory from the surrounding areas. In one of these cases a bacterium was observed which proved fatal to laboratory animals. Whether this organism is tick transmittable is yet to be determined.

In 1932, Wallace (27), Thomas (21) and associates in Illinois, and in 1933 and 1934 Fenstermacher (6, 7) and associates in Minnesota, described a bacterial disease of moose transmitted by the winter tick, *D. albipictus*

Packard. In the latest reports on this disease, similarities to tick paralysis in British Columbia are stressed. A disease is known to be very prevalent in moose in Canada from Northern Alberta and the Maritime Provinces and to cause extremely heavy losses. In 1935, a dead moose, heavily infested with ticks, was reported from Upper Nechako Valley. Later in the same year ticks were received from Hulatt that proved infective and fatal to rabbits, and which on microscopic examination were seen to be laden with bacteria. The disease, presumably attributable to these bacteria, and which to date has not been diagnosed, is decidedly a factor to be reckoned with in game conservation, since it could soon decimate the moose population if it became well established. Unfortunately, the very factor of great increase in game, as is at present noticeable in deer and moose in this province, is apt to augment the dangers from disease.

The Rocky Mountain goat, with his long shaggy coat, is particularly apt to pick up large numbers of ticks, and Buckell (3) described most interestingly his first-hand observations on the worry and annoyance caused by *D. andersoni* Stiles to this particularly fine game animal.

Our own observations at Banff indicate that Rocky Mountain sheep are also very seriously worried by this same tick, and we have on several occasions noted dropped engorged ticks on the bedding grounds, and also spent females with their great masses of eggs. Since these have rarely been noted in nature, it is of interest that in the cases we observed the females had crawled under flat rocks to oviposit.

Unfortunately, there are extant very few records of the ticks infesting the main fur-bearing animals in the province, most of the collecting by the Kamloops laboratory staff having been from the commoner "pest" rodents, such as groundhogs and Columbian ground squirrels. Nearly all the weasels we have taken have been infested, and, in one case, there were nearly 250 ticks (*Ixodes texanus* Banks) on the neck and base of the skull of one of these animals. Specimens of this same tick have also been received from domestic mink on Vancouver Island. Undoubtedly, marten, fisher, and others of the more valuable fur-bearing animals are affected by ticks. Our observations of these animals, however, have been limited, since we are largely dependent upon the interest of trappers for the securing of tick specimens.

Losses from ticks among domestic animals are quite severe at times. Reports to the Kamloops laboratory indicate a great deal of trouble among horse ranchers, from the winter tick, *D. albipictus* Packard, almost every winter. Cameron and Fulton (4) report that in Saskatchewan, out of 150 head of live stock one farmer lost 63 head of cattle and 44 head of horses as a result of infestation with *D. albipictus* Packard. Horses normally appear to be especially favourite hosts among domestic animals, as far as this tick species is concerned. Cattle are much less attacked by this tick, but suffer along with sheep from tick paralysis caused by *Dermacentor andersoni* Stiles. Recent outbreaks in individual cattle ranches in British Columbia have involved, on two occasions 100 and 200 animals. The mortality in these two instances was 60 and 13 per cent, respectively.

As far as man is concerned there are only two species of ticks that are abundant in the province that attach readily, and that are a really noticeable pest, although many other species might occasionally attach as

accidental parasites. One of these, the coast tick, *Ixodes ricinus* Linneaus, has of late been the cause of considerable annoyance to residents in the vicinity of Victoria, B.C. and Vancouver, B.C. The tick is a common pest on pet dogs and readily attaches to humans, often causing sore, slow-healing ulcers. The other, the Rocky Mountain wood tick or paralysis tick, *Dermacentor andersoni* Stiles, is by far the most important species in British Columbia, or for that matter in North America, since it is a serious disease transmitter, especially of Rocky Mountain spotted fever and tularaemia. The former is potentially serious from a public health viewpoint, and during the last season (1936) appeared in two cases at Hedley, the first records for B.C. At the same time there occurred two cases at Manyberries, Alberta, one of which proved fatal.

Tularaemia, while a disease of some rarity, may be quite severe. In 1931, Dr. Ootmar (18) determined a positive agglutination test in a resident at Kootenay, who had contracted the disease at Banff, Alberta. The first case of human tularaemia infection in British Columbia occurred in 1934, at Cherry Creek, Kamloops, and was described by T. K. Moilliet (15).

Human tick paralysis is at present the most serious source of danger from *D. andersoni* Stiles in British Columbia, and cases occur every year in the interior dry belt, there being records at the Kamloops laboratory of over 150 such cases. These data are necessarily incomplete, since many cases occur which are never attended by doctors. A number of deaths among children have occurred, but there is now little excuse for such unnecessary fatalities, as people become educated to recognize early symptoms of the trouble. The disease is at present (1937) under investigation at the Kamloops laboratory.

During 1933 a most interesting outbreak of relapsing fever, suspected to have originated from tick bites, occurred in the Kootenays. Doctors Palmer and Crawford (19) reported on the outbreak, and Hearle (11) discussed the matter with special reference to the vector implicated. In 1935, Herms and Wheeler (12) implicated a new species of tick, *Ornithodorus hermsi* Wheeler, as a vector of relapsing fever. In 1936 there occurred near Vernon, B.C., two human cases which showed characteristics suggesting relapsing fever. It is highly probable that this tick, *O. hermsi* Wheeler, not yet reported from Canada, may be present in British Columbia, and if so be a possible vector of diseases to date not satisfactorily diagnosed.

CONCISE LIST OF IXODOIDEA KNOWN OR THOUGHT TO OCCUR IN BRITISH COLUMBIA

Super-family *IXODOIDEA*.
Family ARGASIDAE (soft ticks).
Genus *Argas*.
Argas persicus Oken.
Genus *Ornithodoros*.
Ornithodoros megnini Duges[1].
" *turicata* Duges[2].
" *hermsi* Wheeler[3].

[1] Almost certain to occur, at least in south-eastern British Columbia as recorded from Alberta and Montana.
[2] Probably occurring in the Kootenay district; nearest record Idaho.
[3] Possibly occurring in British Columbia; only recently discovered, and stated to be widely distributed in the Sierra Nevada and San Bernardino ranges in California at an elevation of 5,000–8,000 ft.

Family IXODIDAE (hard ticks).
Genus *Ixodes*.
Ixodes angustus Neumann.
" *auritulus* Neumann.
" *dentatus spinipalpus* Nuttall and Hadwen.
" *hexagonus* Leach.
" *hexagonus* var. *cookei* Packard (rugose form).
" *kingi* Bishopp[4].
" *marxi* Banks.
" *pratti* Banks[1].
" *putus* Cambridge.
" *ricinus* Linneaus.
" *ricinus* var. *scapularis* Say.
" *signatus* Birula.
" *texanus* Banks.
Genus *Haemaphysalis*.
Haemaphysalis cinnabarina Koch.
Haemaphysalis leporis palustris Pack.
Genus *Dermacentor*.
Dermacentor albipictus Packard.
" *albipictus* Vancouver Island form.
" *andersoni* Stiles.
" *variabilis* Say[4].
Erroneously recorded for B.C.: *Dermacentor occidentalis* Neumann and *Dermacentor reticulatus* Neumann.
Possibly occurring, as recorded from adjacent states: *Ixodes aequalis* Banks and *Ixodes diversifossus* Neumann.

LIST OF HOSTS AND TICK SPECIES TAKEN THEREON IN BRITISH COLUMBIA

(Except where specified these records refer to adult ticks.)

Man.
Ixodes dentatus spinipalpus Nuttall and Hadwen.[5]
Ixodes ricinus Linneaus.
Haemaphysalis cinnabarina Koch.
Dermacentor andersoni Stiles. Adults and very rarely nymphs.
Cattle and Horses.
Dermacentor albipictus Packard.
Dermacentor andersoni Stiles.
Sheep.
Dermacentor andersoni Stiles.
Dog.
Ixodes ricinus Linneaus.
Ixodes hexagonus var. *cookei* Packard.
Ixodes ricinus var. *scapularis* Say.
Dermacentor andersoni Stiles.

[1] Almost certain to occur, at least in south-eastern British Columbia as recorded from Alberta and Montana.
[4] Probably occurring in the Kootenay district; recorded from Montana; Cooley gives distribution for *Ixodes kingi* Bishopp, from Canada to California.
[5] Recorded by G. H, F. Nuttall (16).

Cat.
Haemaphysalis leporis-palustris Packard.
Bear (Grizzly).
Dermacentor andersoni Stiles.
Deer (mule).
Dermacentor albipictus Packard.
Dermacentor andersoni Stiles.
Deer (coast).
Ixodes ricinus Linneaus.
Dermacentor albipictus Packard. Vancouver island form.
Fox (domestic silver).
Ixodes hexagonus var. *cookei* Packard.
Coyote.
Dermacentor albipictus Packard.
Hare.
Haemaphysalis leporis-palustris Packard. All active stages.
Rabbit.
Ixodes dentatus spinipalpus Nuttall and Hadwen.[5]
Ixodes angustus Neumann.
Haemaphysalis cinnabarina Koch.[6]
Haemaphysalis leporis-palustris Packard. All active stages.
Dermacentor andersoni Stiles. All active stages, but adults more rarely.
Raccoon.
Ixodes texanus Banks.[6]
Groundhog.
Ixodes hexagonus var. *cookei* Packard. All active stages.
Haemaphysalis leporis-palustris Packard. All active stages.
Dermacentor andersoni Stiles. Nymphs and larvae.
Packrat.
Ixodes hexagonus var. *cookei* Packard. All active stages.
Dermacentor andersoni Stiles. Nymphs and larvae.
Squirrel (various species).
Ixodes angustus Neumann. All active stages.
Ixodes dentatus spinipalpus Nuttall and Hadwen.[5]
Ixodes marxi Banks. All active stages.
Ixodes texanus Banks. All active stages.
Haemaphysalis cinnabarina Koch. All active stages.
Dermacentor andersoni Stiles. Mainly nymphs and larvae. (One record of adults).
Chipmunk (various species).
Ixodes angustus Neumann. All active stages.
Ixodes marxi Banks. All active stages.
Haemaphysalis leporis-palustris Packard. All active stages.
Dermacentor andersoni Stiles. Mainly nymphs and larvae.
Weasel.
Ixodes hexagonus Leach.[6]
Ixodes marxi Banks. All active stages.
Ixodes texanus Banks. All active stages.

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[5] Recorded by G. H. F. Nuttall (16).
[6] Recorded by C. G. Hewitt (13)

Columbia ground squirrel.
Dermacentor andersoni Stiles. All active stages but mainly nymphs and larvae.
Pika.
Ixodes angustus Neumann. All active stages.
Ixodes dentatus spinipalpus Nuttall and Hadwen. All active stages.
Vole.
Ixodes angustus Neumann.
Mouse.
Ixodes angustus Neumann.
Dermacentor andersoni Stiles. Nymphs and larvae.
Mouse (whitefooted).
Dermacentor andersoni Stiles. Nymphs and larvae.
Pocket Mouse.
Dermacentor andersoni Stiles. Nymph.
Shrew.
Ixodes angustus Neumann.
Shrew (water).
Ixodes angustus Neumann.
Eagle (Alaska bald).
Ixodes auritulus Neumann[6].
Gull.
Ixodes putus Cambridge. All active stages.
Shag (cormorant).
Ixodes signatus Birula. All active stages.
Crow.
Haemaphysalis leporis-palustris Packard. Nymph.
Jay (Queen Charlotte Island).
Ixodes auritulus Neumann. All active stages.
Jay (Stellers).
Ixodes auritulus Neumann. All active stages.
Sparrow (golden crowned).
Argas persicus Oken. Nymphs.
Sparrow (song).
Ixodes auritulus Neumann. All active stages.
Pheasant.
Haemaphysalis leporis-palustris Packard.
Grouse (Blue, including Sooty and Richardson's).
Ixodes auritulus Neumann.
Ixodes ricinus Linneaus.
Haemaphysalis cinnabarina Koch. All active stages but mainly adults and nymphs.
Haemaphysalis leporis-palustris Packard. All active stages but mainly nymphs and larvae.
Grouse (Ruffed or willow).
Ixodes auritulus Neumann.
Haemaphysalis cinnabarina Koch. All active stages but mainly adults and nymphs.
Haemaphysalis leporis-palustris Packard. All active stages but mainly nymphs and larvae.
Dermacentor andersoni Stiles. Nymphs.

[6] Recorded by C. G. Hewitt (13).

Grouse (Oregon).

Haemaphysalis cinnabarina Koch. All active stages but mainly adults and nymphs.

Haemaphysalis leporis-palustris Packard. All active stages but mainly larvae and nymphs.

Lizard (Northern alligator).

Ixodes ricinus Linneaus. Early stages.

REMARKS ON SPECIES

The ticks are divided into two families: The soft ticks, ARGASIDAE, and the hard ticks, IXODIDAE. In the former the capitulum or mouth parts are located ventrally and are not visible from a dorsal view. There are but two genera and no representatives are native to Canada but are occasionally introduced from tropical and sub-tropical regions to the south. Members of the genus *Argas* have thin flat bodies with a distinct sharp-edged lateral margin, whereas the *Ornithodoros* have thick bodies with the margin poorly defined, thick and rounded. Most of the soft ticks have habits rather similar to bed-bugs.

Three genera of the hard tick family, IXODIDAE, are native to British Columbia. In the genus *Ixodes* the anal groove runs in front of the anus, a characteristic not shared by the other genera. Also the males are very distinctive in the possession of a number of ventral plates. Ticks of the genus *Haemaphysalis* are readily characterized by the peculiar arrow-shaped appearance of the mouth parts and palpi resulting from lateral projections of the second joints of the palps. In the genus *Dermacentor* a pair of small "eye spots" are present, one on each side and at the edge of the shield. These are present in larvae, nymphs and adults, and are diagnostic for the genus as far as British Columbia ticks are concerned. They are sometimes hard to detect in engorged nymphs of *D. andersoni*, but otherwise show quite well as pale clear spots.

In the following notes on British Columbia species the merest outline of a summary is given. This will be amplified for publication in a later paper, wherein it is hoped to describe in detail and illustrate all known stages of ticks of Canada.

Family ARGASIDAE.

(a) Genus *Argas*.

(1) *Argas persicus* Oken.

This flat, soft tick, reminiscent of the bed bug in more ways than one, has only once been taken in Canada. It is normally a habitant of warmer southern regions and is quite a serious pest of poultry (and sometimes man) in the southern states, where it is commonly known as the "fowl tick" or "blue bug". To our knowledge it has only been previously taken in North America in the most southerly tier of states and never farther north than California. Our specimens were received through the kindness of Professor Spencer, and were taken by that excellent collector, the late Mr. R. A. Cummings, from golden crowned sparrow at Vancouver on May 2, 1931. These little birds have a friendly habit of coming around houses in the winter in California and could well pick up the ticks when roosting in chicken-yards, and could transport the ticks when migrating north in the spring. Four specimens examined. Nymphs.

(b) Genus *Ornithodoros*.

(2) *Ornithodoros megnini* Duges.

This thick, rather shapeless tick is a southern species commonly known as the spinose ear tick, a very troublesome pest of cattle. Due to its habit of attaching in the ears of the host for long periods, it is liable to be transported considerable distances and can evidently survive quite satisfactorily in Canada since it has been taken in southern Alberta over a period of nearly twenty years. The jack rabbit is apparently the favourite host in northern areas. Hadwen (10) recorded it in 1913, and through the courtesy of Professor E. H. Strickland, specimens taken at Lethbridge on jack rabbits in December, 1931 have been received. While no records are yet available for British Columbia, the species will almost certainly be found in the Kootenay district in southeastern portions of the province. Two specimens examined. Females.

(3) *Ornithodoros turicata* Duges.

This tick is somewhat similar in shape to the last, but differs in that it has a roughened "pebbly" integument. This is a southern species common in parts of South and Central America and as far north as California. Its habits are very similar to those of bedbugs. It has occasionally been transported and established north of its main range, and Dr. R. R. Parker has a record from a mountain camp in Idaho, the nearest actual record to British Columbia. Cases of relapsing fever, a tick-transmitted disease, of which various members of this genus are among the main vectors, lead us to suspect the presence of either this tick or the following species in the Arrow Lakes district of the Kootenays. Drs. Palmer and Crawford (19) of Trail, who report the disease, advance the opinion that *D. andersoni* Stiles may be the vector. While they may prove to be correct, the evidence available does not point that way, and we are of the opinion that an *Ornithodoros* tick has been introduced. No specimens examined.

(4) *Ornithodorus hermsi* Wheeler.

First described in 1935 by Wheeler (28), this tick has since proven to be an important vector of relapsing fever. It has been taken on numerous occasions in California from the nests of small rodents, and, being a high altitude tick, may very likely be present in British Columbia.

This tick, like other members of the genus, is not a specific feeder and will engorge readily on various species of animals including mice, monkeys and man.

(c) Genus *Ixodes*.

(5) *Ixodes angustus* Neumann.

This small brown tick is one of the commonest British Columbia species, especially in the coast district. It also occurs in the interior (Vavenby), but is there largely replaced by *Ixodes marxi*. Squirrels appear to be the favoured host, but a large variety of other small rodents are also utilized to a lesser extent. An interesting point discovered by Dr. Hadwen, who worked out the life-history in detail, is that the male is seldom found on the host but probably stays in the nest of squirrels and other rodents. The nymph and larva are very unlike the adult in certain characters of the palpi. Sixty-one specimens examined. Two males, 36 females and 23 nymphs.

(6) *Ixodes auritulus* Neumann.

This is a bird tick of remarkably wide distribution, occurring commonly on birds in the most southerly tip of South America and also in British Columbia and probably in various Pacific Coast States, according to a recent record by Philip (20). In the coast district this appears to be the commonest tick on grouse, both blue (sooty) and willow. It has been taken in all stages on an extraordinary variety of birds, but does not appear to infest rodents or other small animals. No specimens have been taken in the interior of British Columbia, and it seems to be restricted to the wet coastal area. Thirty-three specimens examined. Eight females and 25 nymphs.

(7) *Ixodes dentatus* var. *spinipalpus* Hadwen and Nuttall.

This rather distinctive species has only been taken to date in the coast district, but it does not appear to be common. Nuttall (16) has recorded it from rabbit, squirrel, and a child at Mt. Lehman, and we have recently examined specimens from pika taken at Alta Lake, B.C. by Mr. Kenneth Racey and loaned us through the kindness of Professor Spencer. Fifteen specimens examined, 3 males, 6 females, 4 nymphs and 2 larvae.

(8) *Ixodes hexagonus* Leach.

We have not been able to place this rather robust thick-legged species in any of our B.C. material, but Hadwen took it at Mt. Lehman on weasel (records by Hewitt (13)). No specimens examined.

(9) *Ixodes hexagonus* var. *cookei* Packard.

We have found this tick to occur quite commonly in all active stages on groundhogs in the interior dry belt, and Hadwen has taken it on dog at Mt. Lehman. One hundred and twenty-seven specimens examined. Twenty-seven females, 53 nymphs and 47 larvae.

(10) *Ixodes kingi* Bishopp.

This species, which resembles *pratti*, and is also apt to be confused with *cookei*, has not been taken yet in British Columbia, but has been recorded from Montana by Cooley (5). Since it has also been taken in Alberta from gopher burrows, it will probably be found in the south-eastern part of this province. We have had the privilege of examining specimens from Wyoming, the type locality, through the kindness of Dr. R. R. Parker, 1 male and 3 females; and also 2 males, 2 females and a nymph in our collection from Medicine Hat, Alta. collected by the late Mr. F. S. Carr.

(11) *Ixodes marxi* Banks.

This is usually considered to be an eastern tick, but we have found specimens that agree very closely with it in the Kamloops and Nicola districts and North Thompson valley. It has been taken almost entirely on pine squirrel, and takes the place of *angustus* on squirrel in the interior, although the latter also occurs, but sparsely. Two hundred specimens examined: 12 females, 81 nymphs and 107 larvae.

(12) *Ixodes pratti* Banks.

This is a species about which much confusion exists. When making his description Banks apparently had at least two species (*pratti* and *kingi*)

before him. In the Nuttall and Warburton monograph (17), Part 2, the description and illustration designated as *pratti*, female, were apparently based on a specimen of *Ixodes kingi* Bishopp, erroneously identified as *pratti* by Banks. Bishopp states, however, that the type specimen of *Ixodes pratti* Banks has definite auriculae (ventral processes on the capitulum), and this at once differentiates the species from *kingi* and most others with which it has been confused. So far no specimens agreeing with *pratti* have been taken in British Columbia, but Dr. R. A. Cooley has recorded it from Montana and Dr. S. Hadwen records it from cat and horse in Alberta; the latter records, however, are more than likely to be really of *Ixodes kingi* Bishopp based on Nuttall and Warburton's key. Further collecting may reveal it in the southeastern portion of the province.

(13) *Ixodes putus* Cambridge.

This is a rather unusual species found on large sea birds, usually attached to the head and neck. It has an extraordinarily wide distribution in Europe, Asia, Australasia and America. There is one previous Canadian record for British Columbia, and one in Eastern Canada. We have examined a female, nymph and larva in the University of British Columbia collection taken by Professor Spencer at Tofino on August 14, 1926, from a dark sea bird. Three specimens examined: 1 female, 1 nymph, and 1 larva.

(14) *Ixodes ricinus* Linneaus.

This is the common tick attacking man in the coast district. When flat it is a very distinctive species, especially the adult female, being a rich red with a reddish-brown shield and legs. It has in recent years greatly increased in numbers, and numerous complaints have been received from Vancouver Island and the mainland from Vancouver to Powell River, B.C. Mr. R. Glendenning has sent us specimens from Agassiz, B.C. and informs us that it is very common in the Agassiz and Chilliwack districts, and constitutes a pest to humans in the spring months. As Gregson (9) has indicated in his paper, the early stages feed on lizards. This is similar to the species occurring abundantly in parts of California as noted by Jellison (14), and recorded as *Ixodes ricinus* var. *californicus* Banks. We do not consider this varietal name warranted, on account of the variation known to exist in European *ricinus*. Specimens of the latter (through the courtesy of Dr. R. R. Parker), and Californian specimens (through the courtesy of Mr. Jellison) have been compared with a very large series from British Columbia, and it was found that variations wipe out the slight difference upon which the varietal name was based. *Ixodes ricinus* is an important vector of certain diseases affecting livestock, especially sheep, in Great Britain, but no trouble in this connection has been noted in this province. Seventy-three specimens examined: 30 males, 37 females, 5 nymphs, and 1 larva.

(15) *Ixodes ricinus* var. *scapularis* Say.

This tick has been recorded from Vancouver by Dr. Hadwen and a specimen has been received from Professor Spencer. This was taken on a dog at Shaughnessy Heights, Vancouver. The outstanding characteristic that readily differentiates it from the true *Ixodes ricinus* Linneaus is that the shield and legs are black. One female examined.

(16) *Ixodes signatus* Birula.

This species somewhat resembles *putus* and also is restricted to sea birds, but is only rarely found on them other than the cormorant. There have been no previous Canadian records, but we have examined females and a large series of nymphs from Brandt's cormorant, *Phalocrocorox pexicillatus* taken by Professor Spencer at Tofino, V.I. on August 5, 1926. In one of the females the porose area was a little like that in *unicavatus*, but other characters indicated *signatus*, in which we place it. This is another species of extremely wide distribution, as is *putus*. Twenty-four specimens examined: 2 females and 22 nymphs.

(17) *Ixodes texanus* Banks.

This was recorded by Dr. Hadwen from raccoon in the Fraser valley, and in the Bella Coola district in the winter, and also from squirrel. We have taken large series in the Kamloops and Nicola district on weasel and squirrel In one case nearly 250 ticks were found on the neck of a weasel. Two hundred and forty-two specimens examined: 5 females, 153 nymphs, 84 larvae.

(d) Genus *Haemaphysalis*.

(18) *Haemaphysalis cinnabarina* Koch.

This is the most common bird tick of Canada, and is a species sometimes causing considerable losses to turkey raisers. It has been found very abundantly on ground game birds in the interior of the province during our tick survey and is particularly troublesome on grouse. It can be separated from the next species by its brighter red-brown colour and by the less acute projection of the second palpal segment; also, *cinnabarina* lacks the small auriculae noted in all stages of the other. It undoubtedly is responsible for the death of many birds, either directly or on account of disease transmission. A fatal case of human tick paralysis at Kamloops was attributed to this species by Todd, but probably in error. Doubtless *andersoni* was attached as well. One hundred and two specimens examined: males 39, females 8, nymphs 10, larvae 45.

(19) *Haemaphysalis leporis-palustris* Packard.

This, in point of numbers, is probably the most abundant tick in Canada. It is distributed almost universally throughout the Dominion. While rabbits are the main host, it also attacks ground-inhabiting birds, such as grouse and meadow larks. Apart from its importance in causing the death of ground game birds, it is a serious factor in the transmission of Rocky Mountain spotted fever and tularaemia from animal to animal, although it does not attach to man, and therefore is not a direct transmitter of human disease. Very large series of all stages examined. Total nearly 2000.

(e) Genus *Dermacentor*.

(20) *Dermacentor albipictus* Packard.

The winter or moose tick is one of the commonest and most widespread of Canadian species. Many recent writers have left the impression that it is mainly a Rocky Mountain tick. This is quite erroneous, since it occurs abundantly from coast to coast, and we have examined or have

records of specimens from almost every province in the Dominion. This is one of the few ticks occurring in America in which all stages remain on the host, instead of dropping between moults. Horses and the larger wild game such as moose and deer are preferred hosts, and man is not attacked. Large mortality is attributed to this tick or diseases transmitted by it. The larval ticks attach in September, and the ticks are on the hosts throughout the winter.

It has been observed that the Vancouver Island form of *Dermacentor albipictus* Packard matures much earlier than that found on the mainland. There are also minor morphological differences such as in the number of goblets in the spiracles. A large series is now being studied and if it is considered that the island form is a new variety, a full description will be published in the near future. Six hundred and sixty-six specimens examined: 71 males, 126 females, 169 nymphs, and almost 300 larvae.

(21) *Dermacentor andersoni* Stiles.

This is the most important of all Canadian ticks and is a serious human health menace. Our records are very extensive for this species, and we find that the distribution is much wider than formerly supposed. Early stages almost invariably attack small rodents, depending on the species most abundant in the locality. Adults also are sometimes found on rabbits, squirrels or Columbia ground squirrels, but mainly feed on the larger animals such as cattle, horses, and man.

The danger from this tick of tick paralysis, spotted fever, tularaemia, and other diseases is so well known that we need not again stress the importance of the species. We have taken larvae from June to as late as November 27, but they are mainly found in July. Adults occur on the host mainly from March to May. Occasionally specimens are found as early as February or as late as November, and we have a number of records in June, July and August, but this is exceptional. One thousand two hundred and thirty-seven specimens examined: 214 males, 251 females, 247 nymphs, and 525 larvae.

(22) *Dermacentor variabilis* Say.

This is the dog tick. It replaces *andersoni* as a pest of man, particularly in Saskatchewan and Manitoba. It is superficially quite like the last species. We have no British Columbia records as yet, but it has been recorded in Montana by Cooley and may possibly occur in the southeastern part of the province. Hadwen has worked out the life-history in detail.

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A FIELD STUDY OF THE FLIGHT, OVIPOSITION AND ESTABLISHMENT PERIODS IN THE LIFE CYCLE OF THE EUROPEAN CORN BORER, *PYRAUSTA NUBILALIS,* HBN., AND THE PHYSICAL FACTORS AFFECTING THEM[1,2]

I. Introduction. History and importance of European Corn Borer in Southern Ontario. Methods of Study.

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Comparatively little is known regarding the critical periods of flight, oviposition and larval establishment in the life cycle of the European corn borer, and much less is known regarding the influence of physical factors on these phenomena. The present systematic field study was conducted during the past ten years to learn the characteristics of these periods, their seasonal and daily variations, and the physical factors, if any, influencing or controlling them. The importance of this detailed knowledge is apparent, but may be emphasized by the following statements.

Larval abundance of, and therefore crop damage by, the European corn borer is largely determined within the periods under discussion, and a biological study in relation to physical or climatic factors shows what has happened in the past and gives an insight as to what may be expected in the future under the same or different conditions.

This information largely governs the development of experimental and practical control methods by means of chemicals or fungus diseases directed against the adult, egg or larva. Marchlewski (8) pointed out as late as 1930 that in order to use chemicals against the moth or larva the biology must be thoroughly known before a suitable control method could be developed, and that, unfortunately, this knowledge was then inadequate from a practical point of view.

It is also desirable to know whether a season is favourable or unfavourable to the increase of the European corn borer when evaluating the success or failure of the only control measure practised on a large scale, namely, that of the destruction or "clean-up" of corn debris from season to season. Caesar (3) stated in 1929 that we could not interpret results of clean-up operations correctly without knowing the effect of the season upon the insect itself.

The work herein reported was carried out at Chatham, Ontario, in the seed corn producing area of Kent and Essex counties. The area is

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[1] A thesis submitted to the Graduate School, University of Minnesota, in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

[2] This subject will be discussed in five articles during consecutive months, in this journal. Subsequent articles will be: II. The flight of the European corn borer. Annual cycle of flight. Daily rhythm of flight. Flight to light trap. III. Flight of European corn borer. The influence of the physical factors upon flight. IV. The oviposition and establishment periods. Annual cycle of oviposition. Daily cycle of oviposition. Flight and oviposition. Egg mortality and survival. Larval mortality and survival. V. The seasonal characteristics of flight, oviposition and larval establishment. The variations and effects of seasonal climate. The factors causing fluctuations in borer populations. Summary. Acknowledgments.

[3] Entomologist in Charge.

of special interest in that during the years 1925 and 1926 the European corn borer damaged the corn crop to a greater extent than in any other locality since its introduction into North America. It is quite probable also that this infestation was greater than has occurred at any time during the history of the insect and within any locality in its known geographical range.

An attempt has been made to retain throughout a broad viewpoint and to correlate the observations and conclusions made in this study with the fundamental problems of insect biology. Where necessary and desirable, these have been pointed out and discussed.

The work was planned and originated by the author in 1926. Since 1927 it has been carried out by the author and various assistants, to whom due credit is given in the section of "Acknowledgments".

CHARACTERISTICS AND DESCRIPTION OF LOCATION OF WORK

Geographical Location

Chatham, Kent County, Ontario, is located at latitude 42° 23′ N. and longitude 82° 12′ W. Its elevation is 595 feet above sea level. It is situated in the southwestern peninsula of southern Ontario on the Thames River, 15 miles east of Lake St. Clair, 12 miles northeast of Lake Erie, and 55 miles northeast of the Detroit River.

Topography

The environs of Chatham, and most of the seed corn producing area surrounding it consist of flat, level plains which were formerly glacial lake bed. At some points along the lake shores the land is dyked.

Climate

The climate of the region is characterized by warm, humid summers, with comparatively mild, more or less open winters. The mean normal monthly temperatures and total mean precipitation, compiled from the records of the Meteorological Service of Canada, are given in Table 1.

TABLE 1.—MEAN NORMAL TEMPERATURES AND TOTAL MEAN PRECIPITATION AT CHATHAM, ONTARIO

Month	Mean normal temperatures in degrees F.	Total mean precipitation in inches	Number of years of observation
January	24	2.19	48
February	22	2.03	48
March	32	2.13	48
April	45	2.29	48
May	56	2.97	48
June	66	2.64	48
July	70	2.81	48
August	68	2.50	48
September	62	2.64	48
October	50	2.47	48
November	38	2.44	48
December	29	2.26	47
Yearly mean	47	29.37	

Figure 1 shows the mean thermohyetic conditions for Chatham.

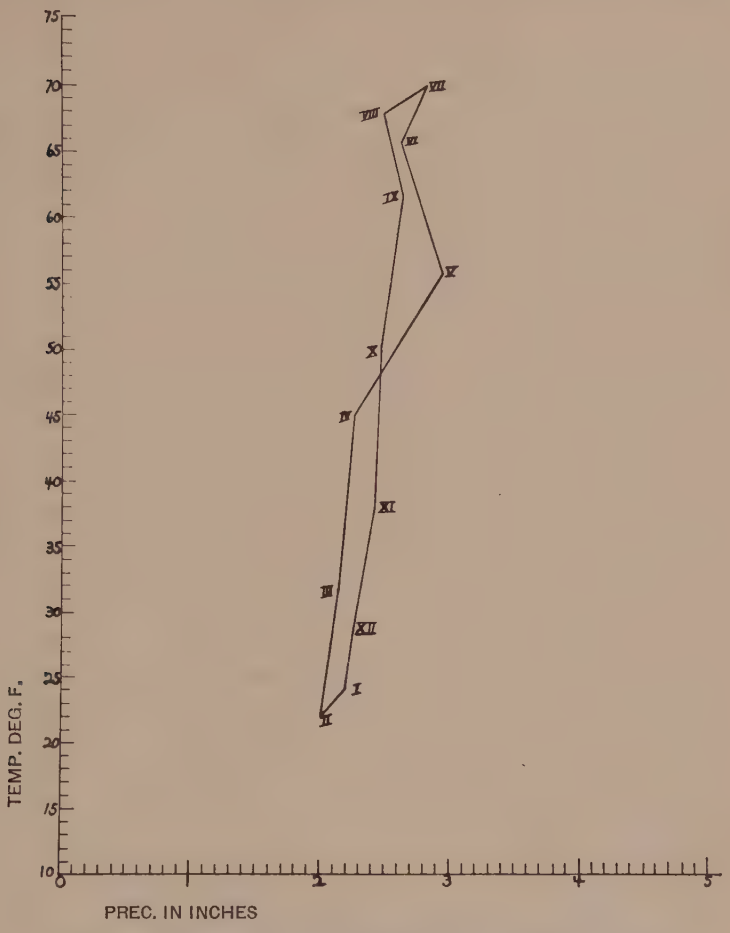

FIGURE 1. Monthly mean thermohyetic conditions, Chatham, Ontario. Based upon 48 years' records.

Original Plant Associations

The area surrounding Chatham, including Kent and Essex counties, lies within the boundaries of the deciduous Forest Formation. Transeau (15) who made a study of the botanical features of the area states that the region was originally dominated by a series of plant associations from Phragmites marsh to swamp forest. The swamp forest of the area was dominated by such trees as American elm, white and black ash, and red and silver maple. The secondary species include pin and swamp white oak, basswood, cottonwood, sycamore, shagbark, and pignut hickory.

Corn and Corn Production

The total corn crop of Ontario in 1935 was 492,509 acres, valued at $12,595,245. Over a period of years the acreage and value have been greater, as in 1922 the acreage was 703,837 valued at $26,262,267.

Corn is an essential factor in the agriculture of the province, being grown mainly for fodder and for seed (husking corn). Almost the entire crop of seed or husking corn is grown in the southwestern portion of the province in the Counties of Essex, Kent and a portion of Lambton, which also produce considerable fodder corn. Chatham is situated in the centre of this area, which is the "corn belt" of Ontario.

The total area planted to corn in these three counties during 1935 was 152,792 acres valued at $3,558,802. Over a period of years the acreage and value run much higher, as may be seen from the figures presented later in regard to corn borer damage.

THE HISTORY AND IMPORTANCE OF THE EUROPEAN CORN BORER IN THE REGION

History

The European corn borer was first discovered in Ontario near Lorraine Station, Humberstone township, Welland county, on August 10, 1920, and near St. Thomas in Elgin county on August 22 of the same year according to McLaine (10). The former location is about 150 miles east of Chatham, while the latter is about 70 miles east. The infestation in Elgin county extended almost to Chatham at the time of its discovery and by 1922 the borer was found in most of the area embraced by the three counties of Kent, Essex and Lambton. By 1924 the percentage of corn stalks infested was 24 in Kent county, 11 in Essex county, and a trace of infestation in Lambton county.

Corn Acreage Reduction and Corn Borer Damage

The borer rapidly increased in numbers in this area and other parts of the province, until in 1926 it ruined the entire corn crop of practically the whole of Essex and Kent counties. Since 1926, the borer has not done a very great amount of commercial damage, but continues in such numbers that it is a very great potential danger to the corn industry. The damage in 1925 and 1926 was the worst ever recorded in the history of the borer either in Europe or America.

The corn borer entered the seed-corn growing area of Ontario at a period when the corn acreage was gradually being reduced mainly because of the low price of corn relative to other crops in 1921, 1922, 1923, 1925 and 1926. Another factor which played some part in the reduction of acreage was the shift to a more intensive agriculture within the region as shown by increased plantings of tobacco and truck crops.

There is no doubt, however, that the corn borer and its damage was largely responsible for and accelerated the already apparent decline in acreage between the years 1924 and 1927 in the seed-corn growing area. Figure 2 illustrates the relationship between corn borer damage and corn acreage reduction.

From Figure 2 it can be seen that a reduction in acreage both in Kent and Essex counties and throughout the Province took place at the time the borer was becoming established. The greatest reduction took place in 1927 following the destruction of the crop of 1926. When the crop of 1927 and later years was not damaged to any extent, the acreage began to increase. Throughout Ontario, as a whole the reduction began somewhat earlier, and naturally was not as severe as in the local area. The

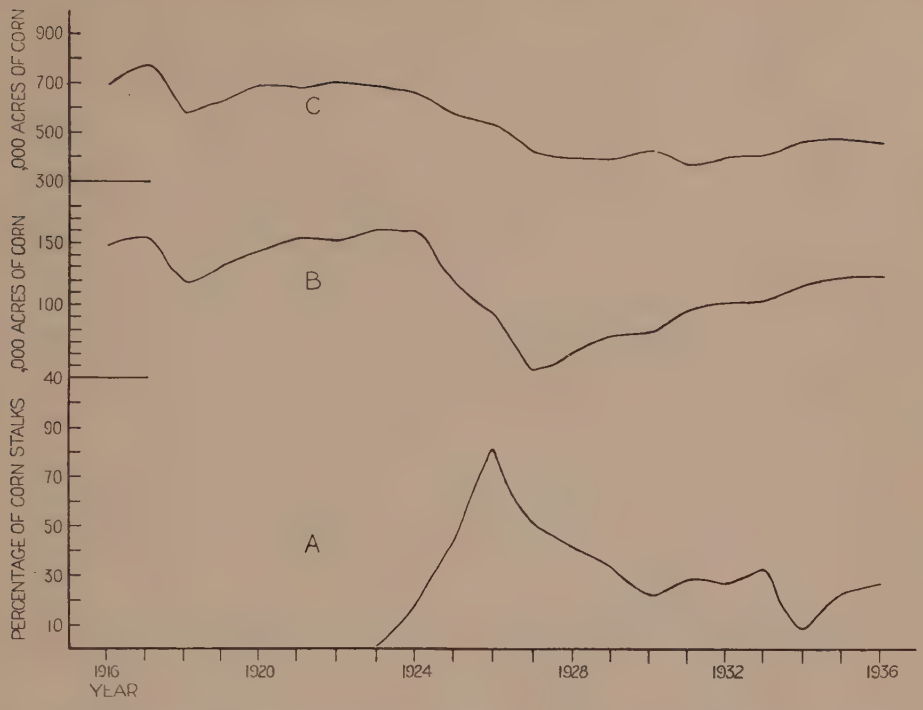

FIGURE 2. Relation between corn borer damage and corn acreage reduction in Essex Kent counties and in the Province of Ontario. A. Average per cent stalk infestation by borer for Kent and Essex counties. B. Total corn acreage, Kent and Essex counties. C. Total corn acreage, Province of Ontario.

curve for Ontario probably shows the effect of the influence of other economic factors to a greater extent than that for Essex and Kent counties, as in the major portion of the Province, the corn borer was not a factor as it either was not yet present or not abundant enough to cause commercial damage.

THE LIFE HISTORY AND CHARACTERISTICS OF THE EUROPEAN CORN BORER IN SOUTHERN ONTARIO

Life History.

The life history of the European corn borer in Ontario has been reviewed in some detail by Crawford (5), Spencer (12) and Stirrett (13). The insect as found in the area is of the univoltine type, as in western New York, Ohio, Michigan, Indiana and other midwestern states. In general, the overwintering larvae pupate early in June and the moths begin to fly during the last few days in June and in July. Oviposition, hatching and larval establishment take place in July, but in some years may extend into early August. Larvae become full-grown within the corn stalks about the last of August and first part of September. With the approach of cool weather they enter hibernation within the stalks.

The average winter mortality found among larvae at Chatham is from 6 to 9%. In other portions of the province the winter mortality may be much higher as shown by Stirrett (14).

Host Plants

Corn is the only primary host of any importance in Ontario and it is very rare indeed to find the borer infesting any other plant.

Parasites and Predators

No egg or larval parasites or predators have been observed by us in our experimental plots during the ten years' work. The same is true of fungus and bacterial diseases. Although imported parasites have, in the past, been liberated in the district, the degree of parasitism found from an annual survey is less than 1% for the entire region. In other parts of the province, namely, in the vicinity of Belleville, imported parasites have killed as high as 30% of the larvae in certain fields. Belleville is approximately 350 miles east and north of Chatham.

OUTLINE AND DISCUSSION ON METHODS OF STUDY

A detailed quantitative field study of the flight of moths has been made at Chatham, Ontario, during the years 1927 to 1936, a period of ten years. The corn plot studies of flight have been supplemented by light trap catches of the moths during the seasons of 1931 to 1936 inclusive and by supplemental corn plots during the years 1929, 1932, 1933, 1934 and 1935.

Field studies on oviposition have been carried on during the seasons from 1927 to 1936 inclusive, while field studies on establishment have been made for the years 1928 to 1936 inclusive. Each year a plot of corn about $2\frac{1}{2}$ acres in extent was grown for these studies. The corn variety used throughout the work was Wisconsin No. 7, a white dent variety of commercial importance in the district surrounding Chatham.

The corn plots of 1927 and 1928 were grown at a different location from those of 1929 to 1936. The plots in these two groups of years were grown about three miles apart. This change in location was unfortunate, but necessary. The plots from and including 1929 were grown on the same location. The plots received the standard field treatments in regard to fertilization, planting, cultivation, hoeing and were located adjacent to Chatham within the market garden and farming district.

Fortunately, there was a good crop each year well up to average for the district.

For convenience of description, the remainder of the methods used will be divided under three headings: methods in study of flight, methods in the study of oviposition and establishment, and the measurement of the physical factors.

Methods of Study of Flight of Moths

Field Plots. Standard Plot "A"

Within the larger plot of corn a flight plot and an oviposition and establishment plot were measured and staked. The flight plot was 80 × 200 feet, or an area of 16,000 square feet in the years 1929 to 1936 inclusive. Such an area contained about 27 rows of corn, 200 feet long.

During the first two years a study of the variation in size of plots was tried out. In 1927, the flight plot size was 40 × 240 feet or 9,600 square

feet, while in 1928 the size was 40 × 120 feet, or 4,800 square feet. It was decided that a larger plot could be handled, and consequently the 1929 plot was increased to the standard size followed during all years since, *i.e.*, 16,000 square feet. In the records used in this paper the actual number of moths captured during 1927 are multiplied by 1.67, while those of 1928 are multiplied by 3.35 to bring the records to the basis of size of plots for the other years.

Studies on the fluctuations in numbers of an insect are possible only by the adoption of a definite quantitative method which allows the investigator to follow the gradations of the species in question year after year.

Observations were made each hour of the night during the flight season over the plot for a period of fifteen minutes to determine the number of moths in the plot. Observations were continued each night until one or no moths were secured in the plot. The first five minutes of each hour were used in recording the physical factors according to the directions given below. After these were secured a search was made of the plot for corn borer moths for a period of fifteen minutes, then the plot was vacated until the next hourly observation. The moths were observed by slowly walking up and down the corn rows and illuminating the plants or moths in flight by use of a four-celled flashlight. After some practise, moths could readily be seen in flight or resting on the corn plants. Adult corn borers fly rather slowly in contrast to many of the other Lepidoptera. Their light colour also helps in readily distinguishing them while flying. Without some practise they might be confused in flight with *Haematopsis grataria* Fabr., a geometrid moth of the same size as the corn borer adult. It is also light in colour, being a pinkish-yellow. The male and female corn borer moths can also readily be differentiated by their character of flight; the female, somewhat the larger, is lighter in colour and flies much more regularly or steadily than the smaller, darker, swifter male.

When a moth was observed, it was caught if possible, its sex determined by squeezing the abdomen to extrude the genitalia and then killed.

It generally required the full fifteen minutes to patrol the plot. One could regulate his speed after some practise to cover the plot in the time required. If one finished the plot before the time limit, the remainder of the time was spent in repeating the observations in the plot until the time was up.

In the early years of work, each row of corn was examined; later when moths were fewer in number, three rows of corn were examined at a time.

Flight records and meteorological observations were recorded on a mimeographed record sheet. A new sheet was utilized for each hourly observation.

During the first two or three years, observations were begun on Eastern Standard time, and there was some variation in the time of commencing observations; later all observations were made in sunset time and the observations were begun exactly on time at the time indicated in the records. All records in regard to flight are given in sunset time. The records for the earliest years are given to the nearest hour, but do not vary more than twenty minutes from the time indicated.

The time at which sunset occurred at Chatham, Ontario, for the years and dates under consideration is given in Table 2. The author is indebted

to Mr. C. C. L. Gregory, Wilson Observatory, University of London, England, through Mr. Geoffrey Beall, for these calculations.

TABLE 2.—SHOWING EASTERN STANDARD TIME (P.M.) AT WHICH SUNSET OCCURS AT CHATHAM, ONTARIO

Date	Time	Date	Time	Date	Time	Date	Time
June 28	8:10	July 8	8:8	July 18	8:2	July 28	7:53
29	8:10	9	8:7	19	8:1	29	7:52
30	8:10	10	8:7	20	8:1	30	7:51
July 1	8:9	11	8:6	21	8:0	31	7:50
2	8:9	12	8:6	22	7:59	Aug. 1	7:49
3	8:9	13	8:5	23	7:58	2	7:48
4	8:9	14	8:5	24	7:57	3	7:47
5	8:9	15	8:4	25	7:56	4	7:45
6	8:8	16	8:3	26	7:55	5	7:44
7	8:8	17	8:3	27	7:54		

These average values are not strictly true from year to year, but they are not in error more than one minute if applied to any year. Sunset is taken to be the moment at which the upper rim of the sun apparently sinks below the horizon.

In comparing Sunset time and Eastern Standard time, the following are the equivalents for July 12.

Sunset Time	Eastern Standard Time	Sunset Time	Eastern Standard Time
—:30*	7:36 p.m.	6:30	2:36 a.m.
:30	8:36 p.m.	7:30	3:36 a.m.
1:30	9:36 p.m.	8:30	4:36 a.m.
2:30	10:36 p.m.	9:30	5:36 a.m.
3:30	11:36 p.m.	10:30	6:36 a.m.
4:30	12:36 a.m.	11:30	7:36 a.m.
5:30	1:36 a.m.	12:30	8:36 a.m.

* —:30 means 30 minutes before sunset.

At —:30 Sunset time, it is still daylight at Chatham during the summer months. Dawn or sunrise occurs between 6:30 and 7:30 Sunset time.

If Standard time had been used each succeeding night the observations would be taken later with respect to Sunset time and an error would be introduced between supposedly parallel observations. If observations from a year with early flight be compared with those of a late one, the error would be greater.

Field Plots. Supplementary Plots. Plot "B"

In certain years, flight observations were made in plots of corn belonging to farmers in the neighbourhood. These plots were utilized on certain nights in 1927, and during the seasons 1929, 1932, 1933, 1934 and 1935. The plot areas were exactly the same as in our own standard plot "A", so that direct comparisons could be made between the plot. The observations were made in exactly the same manner as described above.

Light Trap Studies

During the years 1931 to 1936 inclusive, a light trap was operated in a farmyard one mile distant from the standard plot "A". The trap was

a deGryse (6) type trap, fitted with a 100-watt, white frosted electric bulb. The bulb was renewed frequently in order to have a fairly constant light intensity. The light was operated from April until about October 20. It was lighted each night about 6:30 p.m. The light trap catches were examined daily for corn borer moths. These were recorded according to sex. The insects were killed by the use of calcium cyanide dust deposited in the bottom of the trap. It was replenished every other day in order to keep the gas at a high and more or less uniform concentration. On certain nights several thousands of various kinds of insects have been collected in this trap.

In the flight records throughout the paper, the Standard plot is designated plot "A", while the secondary farmers' plots when used are designated plot "B". The light trap catches are referred to as "C".

Methods in the Study of Oviposition and Establishment

Definition of Larval Establishment

Larval establishment is understood to mean that after hatching the larval settle down within the host plant to a successful life of feeding and growth. To become established, the larva must continue to live and develop, at least for a period of time. Larvae hatching, entering the corn plant, and living successfully to a period just before the commencement of autumn migration are said to be established.

Oviposition and Establishment Plot

A short distance from the flight plot and within the laboratory field of corn an oviposition and establishment plot was made each year beginning with 1928. In 1927, oviposition records only were taken. The oviposition and establishment plot consisted of staked and marked corn plants upon which egg laying, hatching and establishment records were taken throughout the season. The plants for this plot were thinned so that only one plant, without suckers, was allowed to grow at any given point. The plants were 36 inches apart each way, unless, of course, a plant died or was accidentally taken out.

The plot consisted of two parts; the two outside rows of corn on each of the four sides of the plot was termed the buffer plot because it was to act as a buffer between the establishment plot proper and the corn plants in the general field. On it egg masses were observed, the eggs counted and then destroyed. The inner remaining plants were called the plot proper. On it eggs were observed, counted, marked, and continued under observation until they hatched, when the larvae were allowed to establish themselves within the plant. Thus, any larvae found on the buffer plot must have come either from the plot proper or from the corn surrounding the plot, while any larvae found in the plants of the plot proper must have come from eggs laid on the plants in this portion of the plot.

The corn stalks in both the plot proper and buffer plot were dissected and examined for established larvae between August 20 and August 22 of each year. This date is just before the early autumn migration of the borer. Any larvae found in the plants at this time whether dead or alive were said to have become established. It was only very rarely that dead larvae were found. Only larvae found in the plot proper and the inner

row of the buffer plot were said to have become established and used in the calculations of establishment.

The oviposition and establishment plots varied somewhat as to the number of individual plants which they contained each season. The numbers in the plot for each year are as follows:

1928 — 176 plants
1929 — 191 plants
1930 — 122 plants
1931 — 189 plants
1932 — 148 plants
1933 — 143 plants
1934 — 144 plants
1935 — 132 plants
1936 — 132 plants

It took the services of one man at least a full morning to examine these plots and make the necessary observations.

It was intended that the plants should be examined and records taken each day during the season. However, in some years this was not possible and the observations were made every other day. They were made every day during the years 1928, 1931, 1932, 1933, 1934, 1936, and every other day during 1929, 1930 and 1935. The eggs very rarely hatch within three days and therefore no eggs could be laid, hatch and disappear before being examined.

When egg masses were found they were marked with an indelible pencil on the leaf near egg mass and recorded in a notebook according to row number, plant number, leaf number, and etc. There was very little chance of the mass becoming lost or records being confused. Sometimes when it was very hard to count the number of eggs in a mass, the counting of the individual eggs was left a day or two until embryonic development made the individual eggs more easily recognizable.

The oviposition and hatching observations were made on the morning or afternoon of the day following the flight of moths but throughout this paper, oviposition records are given under the date of the night the eggs were actually laid and not the day they were examined.

Planting Dates and Maturity of Corn

It is a well known fact expressed by numerous authors and observed and studied by ourselves on a number of occasions that the number of moths attracted to any given field of corn depends upon the maturity of corn as expressed by height of plant, date of tasselling, date of silking, and other criteria. The highest corn in any given region will attract the most moths and will, therefore, have the most eggs laid upon it. Moreover, it is well known that the amount of larval establishment is influenced by such factors as maturity of corn, growth habit, varieties, density of larvae and other factors not yet clearly defined.

In this study of the fluctuations of the number of moths flying, the number of eggs deposited, in egg mortality and in larval mortality and their correlation with the physical factors from year to year, these varying factors have been eliminated as much as possible by the use of only one variety of corn throughout the work and by planting the plots at the same or corresponding phenological time each year.

The height of corn in the plots has varied from year to year, but so have the dates of flight and oviposition, and therefore the height of corn

(maturity) from year to year would have no significance in regard to the relative attractiveness of the corn to moths on the same date. The corn height each year would, however, have a marked significance in comparing the flight or establishment as found in our plots with that found in adjacent plots in the same season.

The corn has been planted each year at the best planting date for the season and region. This date is utilized by the largest number of corn growers, and corn planted at such dates should give corn which would attract the same number of moths and have practically the same rate of establishment as the large proportion of the corn crop of the district.

The plots show the numbers of moths attracted and the same rate of establishment as the great bulk of the corn of the region for each season. They do not show the number of moths or establishment rate as found in very early or late fields. That this is so is proven by the very close relationship between the numbers and seasonal occurrence as found in our plots and that shown by light trap catches which are not influenced by the growth of corn.

One might compare the height of corn on any fixed date from year to year. However, since any such date falls at a different point in the progress of flight from year to year, it would appear more satisfactory to refer the height of corn from year to year to some relatively fixed point in the progress of flight. Accordingly, it has been referred to the apparent peak of flight.

The height of the corn in plot "A", at the time of the peak of moth flight, is given below. The height of corn is the distance from the ground surface to the upper part of the bend in the topmost leaf of a plant. The average is based on at least the measurement of two hundred plants selected at random in the plots.

Year	Date of peak of moth flight	Average height of corn in inches	Year	Date of peak of moth flight	Average height of corn in inches
1927	July 12	18	1932	July 7	27
1928	July 16	23	1933	June 29	22
1929	July 7	12	1934	July 12	30
1930	July 8	27	1935	July 11	37
1931	July 9	31	1936	July 9	30

The tasselling and silking dates have been recorded during the past four years and are given below.

Year	Average date of tasselling	Average date of silking	Year	Average date of tasselling	Average date of silking
1933	July 16	July 29	1935	July 24	Aug. 3
1934	July 16	July 27	1936	July 16	July 30

The planting dates may also be of interest and they are as follows:

Year	Date	Year	Date	Year	Date	Year	Date
1927	June 5	1930	May 26	1932	May 31	1935	May 21
1928	June 5	1931	May 26	1933	May 23	1936	May 20
1929	June 6		and 27	1934	May 21		

The later planting dates of the first three years were brought about by seasonal conditions, but also because it was the general practise of the farming community to delay planting in order to avoid damage from the borer. After three years without much damage, the original general planting date was again taken up.

In regard to "B" plots studied, that of 1929 was an early field of sweet corn planted May 14. It was much more mature and taller than plot "A" of the same year at the time of moth flight. It was situated about three hundred yards from plot "A". The 1932 plot was also an early plot of sweet corn, two miles distant from plot "A". In 1933, plot "B" was in a field of yellow dent corn planted about June 1, that is, one week later than plot "A". It was about one-quarter mile from plot "A". In 1934, plot "B" was in a field of yellow dent corn planted May 22. It was a little less than one-quarter mile from plot "A". In 1935, plot "B" was in a field of yellow dent corn planted May 22. It was in the same location as in the previous year.

It will be noted that plots "B" for 1934 and 1935 were planted at the same time as our own plot "A".

Measurement of Physical Factors

All of the physical factors were measured within the corn field at the time of observations on flight, and for the studies on oviposition and establishment other records were secured throughout the season by the use of a recording hygrothermograph set up in the field.

It has been shown by Miller and Saunders (11) that the temperature on the upper surface of turgid corn leaves between 9:00 a.m. and 4:00 p.m. in direct sunlight is essentially the same as that of the surrounding air. In one thousand determinations they found that the average temperature on the surface of a corn leaf was 30.64° C., while that of the surrounding air at the same time was 30.58° C. It would appear, therefore, that a temperature recording instrument in the field would give a very accurate measure of the temperature being experienced, say, by eggs on a corn leaf.

Temperature

During the first year, temperature was obtained by use of a Taylor Instrument Company sling psychrometer. During the second and later years, it was obtained from a Friez thermograph placed within a standard weather bureau type shelter. At the time of night when observations on flight were being taken, the door of the shelter was left open to facilitate readings. The thermograph was checked and corrected for temperature at least once a week and generally more frequently during the flight season. The instrument within the shelter was four feet from ground surface. Temperatures throughout the paper are given in degrees Fahrenheit.

Atmospheric Humidity

In the field, this factor was determined as relative humidity by the use of a sling psychrometer during the first year and by use of a Friez hygrothermograph in subsequent years. The hygrothermograph was checked at least once a week against a sling psychrometer. It was enclosed in the same shelter as mentioned above under the heading "Temperature."

For the purposes of this paper, humidity is given in terms of saturation deficiency expressed as a vapour pressure in millimetres of mercury. This factor has been calculated for all observations from the temperature and relative humidity records by use of the nomogram for saturation deficiency determinations designed by John R. Baker (1) at Oxford University. The method was checked with the longer mathematical calculations for saturation deficiency determinations as described by Bates and Zon (2) and the necessary values supplied by Marvin (9). The observational method was found to be accurate to within the second decimal place.

Evaporation

This factor was not recorded during 1927. In subsequent years it was obtained by the use of Livingston standardized spherical atmometers. These were utilized in a Graham type set-up as described by Chapman (4). Usually, three atmometers were used at one time. These were exposed for five minutes and the average evaporation for the three instruments was used as the evaporation rate for the observation. The readings were corrected by the utilization of the coefficient stamped on each atmometer sphere. The utilization of three atmometers at one time eliminated the risk of losing records, as it was found that atmometers need constant care and attention if they are to be used successfully, and frequently one instrument would be out of order just at the time it was required. Evaporation is recorded in cubic centimetres of water evaporated per five minutes.

Rainfall

This was unrecorded in the plots during the first year and for this season the rain records of the Chatham Station of the Meteorological Service of Canada are utilized. This Station is situated about one mile from the plots. For all other years, rain was recorded at the edge of the corn field by use of a standard rain gauge. Rain is recorded in inches.

Atmospheric Pressure

For the years 1927 to 1934, inclusive, the barometric pressure readings used are those of the Chatham Weather Station of the Meteorological Service of Canada. Pressure was read at 8:00 a.m. each day. The Station is situated about one mile from observation plots. In 1935, we were able to purchase a mercurial barometer of our own, and for the years 1935 and 1936 records were taken one hour before sunset and again after the flight period had ended for that night, thus giving the change in pressure per hour during the time the moths were in flight. All readings were corrected for temperature and are given in inches of mercury.

Wind

Wind was measured in the field by use of a Biram portable anemometer. The instrument was set on a platform four feet from the ground. Five readings of one minute each were used to give the average wind velocity

for the period. It was found later in the work more desirable to take one five-minute reading. Readings were corrected according to the directions of the manufacturers of the instrument. The instruments were also checked for accuracy from time to time by the Physical Laboratory, National Research Council, Ottawa.

Wind is recorded in feet per minute. To convert the speed into miles per hour, feet per minute are multiplied by .01136. Similarly, if miles per hour squared is multiplied by .005, one obtains pressure per square foot.

Moonlight

Data regarding the phases and ascension of the moon at Chatham, Ontario, were obtained from the Canadian Almanac. Field records were made in regard to whether or not the moon was "in" or "out" at the time of observations.

Cloudiness

The general condition of the sky in regard to amount of clouds present at time of flight observations was recorded.

Light

The market was surveyed to obtain an instrument for the measurement of light intensity at night, but none could be found, until finally, in 1931 the ecophotometer as designed by Dr. A. B. Klugh (7) of Queen's University, was purchased and tried. This instrument was designed for daylight use and after a thorough trial it was found unsuitable for night work. The percentage transmission filter with which the instrument was fitted was too dense for light intensity at night and very little registration was obtained upon the panchromatic plates.

Dew

In the earlier years, the presence or absence of dew was observed irregularly. It was noted, however, that during the early years of work the dew was usually heavy. Later, regular observations were made and are complete for a number of years.

In 1936, a dew measuring instrument made by Wilh. Lambrecht, Germany, was loaned by the Meteorological Service of Canada for trial. Unfortunately, there was very little dew during the flight season and an adequate trial of the machine was impossible.

Guttation

As will be discussed later, guttation is a frequent phenomenon in the corn plant. A record of its presence or absence and abundance has been recorded for a number of the years.

(To be continued.)

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MALLING STOCKS AND FRENCH CRAB SEEDLINGS AS STOCKS FOR FIVE VARIETIES OF APPLES. II[1]

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At the end of the fifth year in the orchard a first report (5) on the Malling apple stock trial at the Ontario Horticultural Experiment Station was issued. The stocks under test and their classifications are as follows: French Crab seedlings and Malling XVI, very vigorous; Malling I, vigorous; and Malling II, semi-dwarfing. The present report, at the end of the eighth year, completes the records up to the end of 1937. As the building of a new highway has resulted in the loss (November 1937) of a few trees at one end of this orchard a summary of the results including these trees seems advisable at this time.

GROWTH

In a general way there has been little change since 1934 in the relative sizes of tree on the various stocks. In three varieties French Crab trees are the largest while Malling XVI trees are the largest in the other two varieties. Malling I trees are significantly the smallest except in Spy where the differences between Malling I and Malling XVI are not significant. Malling II trees show a tendency towards dwarfness in R. I. Greening, Melba, and Delicious, but this tendency is not so evident in the other two varieties. The trend of growth on all of these stocks is illustrated in Figures 1, 3, 5, 7 and 9.

The trees in this orchard have been given a light pruning each year, and to reduce variation in pruning treatment all the work has been done by the writer. The figures given in Table 1 show that there is, in a general

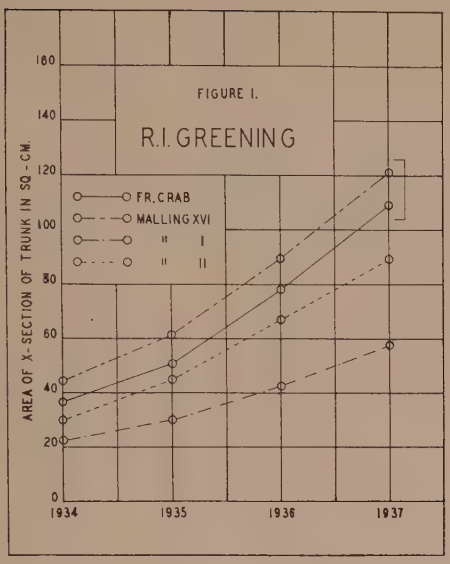
TABLE 1.—WEIGHT OF PRUNINGS, MEAN OF 16 TREES, 1931-37 INCLUSIVE (KGMS.)

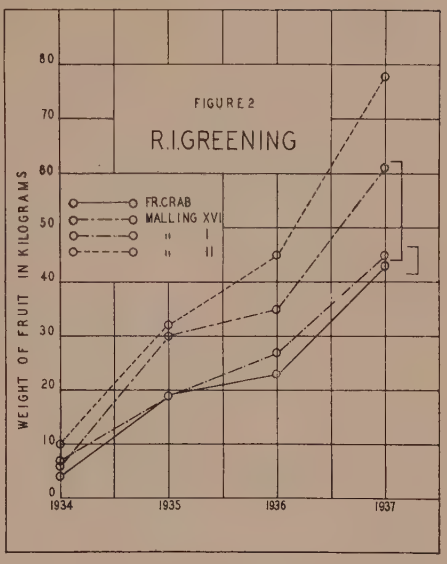
——	French Crab	XVI	I	II
R. I. Greening	2.50	5.20	2.04	3.13
Melba	1.90	1.62	0.91	1.26
Delicious	1.77	1.36	0.99	1.15
Spy	0.69	0.53	0.40	0.45
McIntosh	2.29	1.48	1.24	1.42

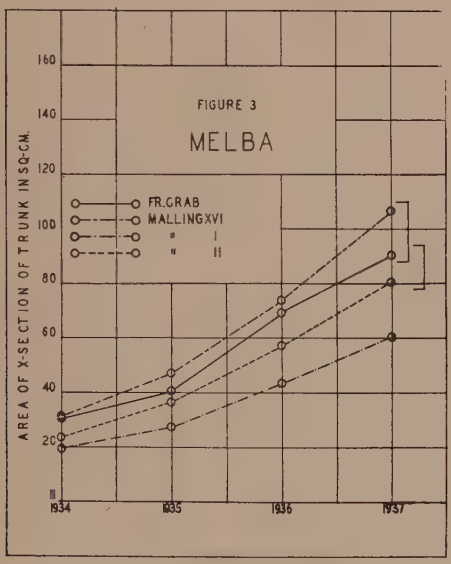
way, a positive correlation between size of tree of a certain variety and the weight of prunings taken from those trees. However, heavy fruit production in weighting down the branches plays a part by its demand for the removal of those branches which hinder cultural operations.

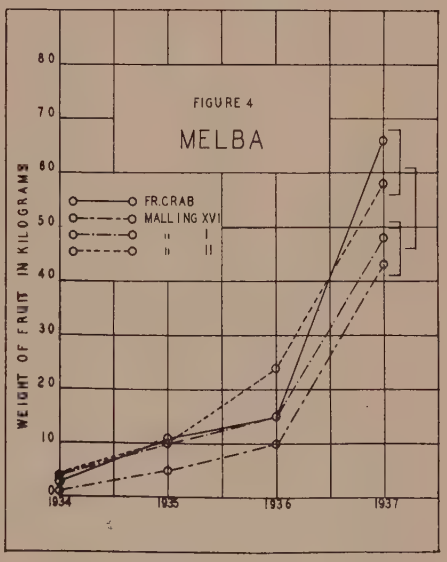
[1] Presented at the meeting of the American Society for Horticultural Science, December 28-30, 1937.

[2] Associate in Research.









FIGURES 1 and 3. Comparative tree size of R. I. Greening and Melba on four stocks. Yearly area of cross section of trunk, means of 16 trees of each variety on each stock, have been plotted. 1937 measurements within brackets are not significantly different.

FIGURES 2 and 4. Accumulated yield of fruit, means of 16 trees. Yields bracketed together were not significantly different in 1937.

YIELD OF FRUIT

There has been enough fruit of all varieties, except Spy, to give some indications of precocity and early yields. The accumulated yields are given in Figures 2, 4, 6, 8 and 10. Malling II trees lead in yield per tree except in Melba, where French Crab trees have been slightly but not significantly more productive. Except in R. I. Greening, Malling XVI

trees seem to be even later in coming into bearing than French Crab seedling trees and in yield are still behind the trees on the other stocks.

In order to show the productiveness of trees on the various stocks for a constant area of trunk cross section, the only available measure of tree size in this trial, Table 2 has been compiled. Malling I and II share the honours, each being in the lead in two varieties. The only combination approaching Malling I and II trees is Melba on French Crab seedlings. Spy has not been included in this table because the yield has been too small to have any significance.

TABLE 2.—YIELD OF FRUIT (KGMS.), 1930-37 INCLUSIVE, PER 100 SQ. CMS. OF TRUNK CROSS-SECTION

——	French Crab	XVI	I	II
R. I Greening	39	50	78	**87**
Melba	72	40	**80***	72
Delicious	10	4	34	**36**
McIntosh	57	42	**90**	75

* The high reading for each variety is given in bold face type.

GRADE OF FRUIT

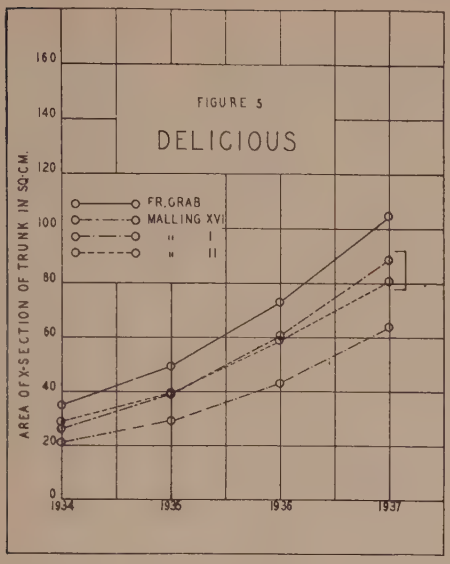
In 1936 and 1937 there was sufficient fruit of all varieties, except Spy, to make commercial grading worth while. First they were graded by hand into No. 1 and Domestic grades and then the machine separated the apples into the following diameter classes: below 5.7 cms.; 5.7 to 6.3 cms.; 6.4 to 7.0 cms.; 7.1 cms. and up. There was a very small percentage of the apples below 5.7 cms. in diameter.

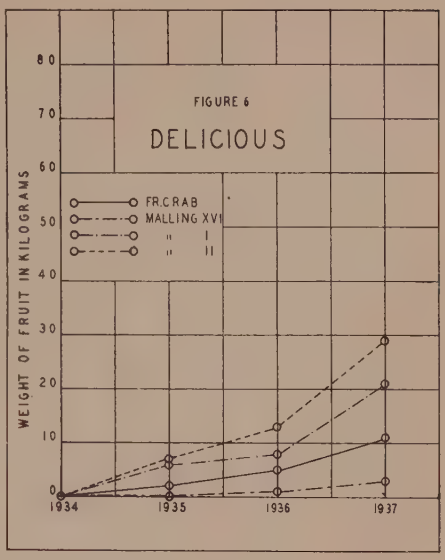
All of the trees on the Malling stocks of a given variety were propagated from buds of one strain, but in three varieties this strain could not be obtained on French Crab seedling roots and as a result the Delicious, McIntosh, and Spy trees on this stock are a different colour strain to the Malling trees and therefore not comparable to them in grade of fruit. Colour of fruit is a major factor in grade classifications so much so that, within a colour strain, grade can be used as an index to fruit colour. With this in mind the percentages of No. 1 fruit, averages of 1936 and 1937, from the stock-scion combinations are given in Table 3.

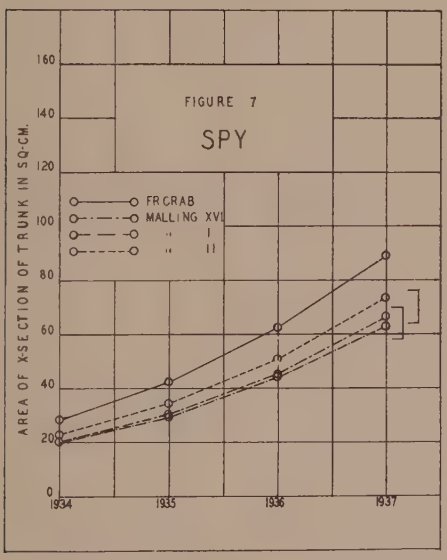
TABLE 3.—NO. 1 APPLES AS PERCENTAGES OF THE TOTAL CROP, AVERAGES OF 1936 AND 1937

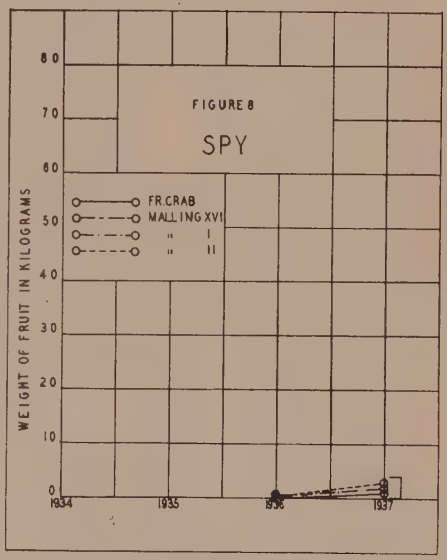
——	French Crab	XVI	I	II
R. I. Greening	48	53	**60***	56
Melba†	37	36	33	**39**
Delicious	73‡	70	**84**	76
McIntosh	58‡	**70**	44	50

* The highest percentage for each variety is given in bold face type.
† 1937 only; hail injury in 1936 resulted in reduction of No. 1 fruit to negligible proportions.
‡ Different colour strain to the other trees and therefore not comparable to them.









FIGURES 5 and 7. Comparative tree size of Delicious and Spy on four stocks. Yearly area of cross section of trunk, means of 16 trees of each variety on each stock, have been plotted. 1937 measurements within brackets are not significantly different.

FIGURES 6 and 8. Accumulated yield of fruit, means of 16 trees. Yields bracketed together were not significantly different in 1937.

Too much significance must not be attached to the figures in Table 3 since they represent the records of only two years and of a period when the trees are still quite young. In spite of heavier crops for a given tree size (Table 2) Malling I and II trees have produced very high grade fruit. McIntosh apples from Malling XVI trees were decidedly better in colour

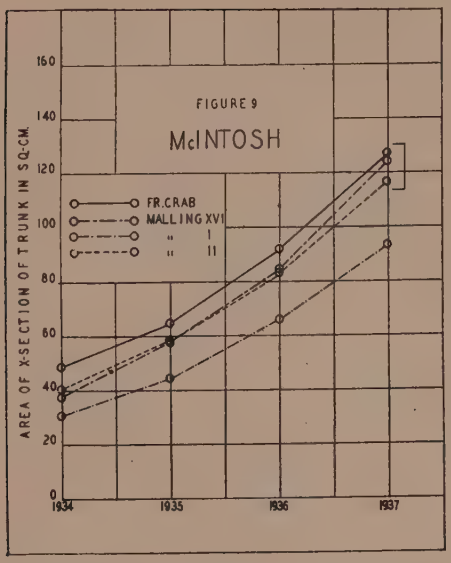


FIGURE 9. Comparative tree size of McIntosh on four stocks. Yearly area of cross section of trunk, means of 16 trees on each stock, have been plotted. 1937 measurements within brackets are not significantly different.

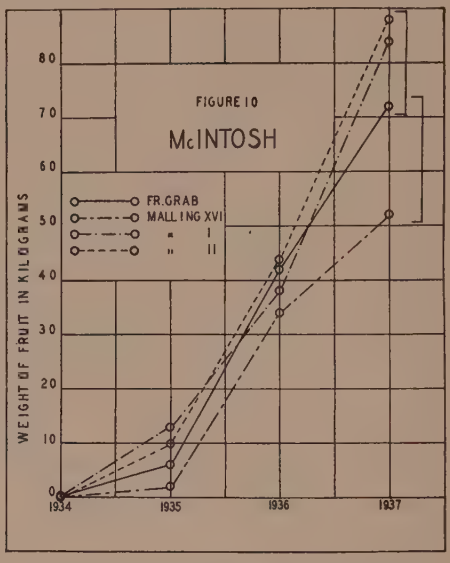


FIGURE 10. Accumulated yield of fruit, means of 16 trees. Yields bracketed together were not significantly different in 1937.

in 1936 than those from the other combinations but in 1937 the difference, though still in favour of Malling XVI, was comparatively small.

From the size grading figures the average diameters of apples from the stock-scion combinations can be computed with a reasonable degree of accuracy, and the results are given in Table 4. It is quite obvious that during these two years the differences in size of fruit were insignificant. Melba was lightly thinned in 1937 but this was the only thinning done in either year.

TABLE 4.—MEAN DIAMETER (CMS.) OF APPLES COMPUTED FROM SIZE GRADING FIGURES OF 1936 AND 1937

——	French Crab	XVI	I	II
R. I Greening	7.2	7.2	7.2	7.2
Melba	7.1	7.1	6.9	6.9
Delicious	7.1	7.1	7.0	7.0
McIntosh	7.1	7.1	7.1	7.1

EVIDENCES OF POTASSIUM DEFICIENCY IN THE TOP AS AFFECTED BY STOCK

In this orchard there is no doubt about the presence of a potassium starvation condition. Soil tests made in the fall of 1936 show that the readily available potassium is low in the surface soil and very low in the subsoil. From the spring of 1934 to the fall of 1936 eleven hundred pounds per acre of sulphate and muriate of potash have been applied on the surface

and immediately disked in, and in addition there was an application of barnyard manure at the rate of 15 tons per acre in the fall of 1935. From 1934 to 1937 buckwheat and rye have been the green manure crops. Leaf scorch, generally recognized as an evidence of potassium deficiency, has been evident to a certain extent on all varieties, but R. I. Greening has shown by far the most pronounced symptoms. On this variety records of amount of leaf scorch have been taken in 1935, 1936 and 1937 (Table 5).

TABLE 5.—ESTIMATED PERCENTAGE OF R. I. GREENING LEAVES SHOWING LEAF SCORCH, MEANS OF 16 TREES ON EACH STOCK

——	French Crab	XVI	I	II
1935	42	32	71	35
1936	28	8	48	20
1937	48	41	70	48

It appears that Malling I trees are suffering from potassium starvation to a much greater extent than are the trees on the other stocks. It is quite conceivable therefore, that this condition may explain why Malling I trees are so much smaller than the other trees (See Figures 1, 3, 5, 7 and 9). On a soil well supplied with readily available potassium the comparative tree sizes might be quite different. Malling XVI trees seem to be suffering least of all from potassium starvation, and in R. I. Greening they are outstanding in vigour of growth. In spite of heavy applications of potassium fertilizers in the past three years there has not yet been any lasting improvement in the condition of the foliage. In 1936 there seemed to be considerably less leaf scorch but in 1937 there was even more than in 1935. It is quite likely that the fluctuations are due to seasonal factors and that the added potassium has not yet become accessible to the roots.

VARIABILITY

Since 1934 there has been still further reduction in the coefficient of variability of the cross sectional area of the trunk of the trees on these stocks (Table 6). With the exception of Malling I trees all coefficients are now about 20 which represents a fair degree of uniformity in growth. French Crab seedling trees are no more variable than are the trees on the clonal stocks. During the past three years the size variability of Malling I trees has not been reduced to the same extent as it has with the other stocks. A possible explanation is the variable supply of potassium in the soil as it is quite evident that some of the R. I. Greening trees on Malling I are suffering from potassium starvation to a much greater extent than are other trees of the same combination.

The variability in yields (Table 6) is very much greater than the variability in trunk measurements. As variation in time of coming into full bearing and the biennial bearing habit enter into the yield figures it was probably inevitable that the yield variability would be high but it is surprising to see such a spread between the two sets of figures.

Scion rooting has not been any considerable factor in adding to the variability of the trees in this orchard. In the fall of 1937 all of the trees

TABLE 6.—COEFFICIENTS OF VARIABILITY

	French Crab	XVI	I	II
Area of x-section 1934	26	25	32	31
of trunk (mean of 5 varieties) 1937	19	18	29	21
Yield, 1930-37 (mean of 4 varieties, Spy not included)	59	54	49	46

were examined for scion rooting. Only about 5% of them had scion roots and these mostly small in size; another 5% had roots so close to the region of the union that it was impossible to determine whether or not they were scion roots. All of the scion roots and most of the doubtful ones were cut off at this time. Trees on Malling I stocks had scion rooted to a greater extent than any of the others. Unless scion rooting is desired it appears to be advisable to plant fruit trees no deeper than they were in the nursery row.

MALLING IX

As the number of trees on Malling IX stock is very limited and as they are not interplanted with the trees on the other stocks but situated at one side of the orchard no direct comparisons have been made. Yet the data even though limited, seem to be worth presentation. One of the Spy trees was found to have a very large scion root and had to be eliminated from the records, reducing the number from nine to eight trees. This same scion-rooted tree has produced only 4 kilograms of fruit while the non-scion-rooted Spy trees have averaged 63 kilograms per tree. A few trees of the other varieties were found to have small scion roots which were removed in the fall of 1937. It is quite apparent that scion rooting may be a serious problem in the case of trees on Malling IX stocks as the scion roots may soon predominate over the original root system, resulting in the loss of the dwarf habit and early fruiting.

All varieties except Spy have been very considerably dwarfed by the Malling IX roots (Table 7) and, in view of heavy fruit bearing, it is surprising that Spy has continued to grow so vigorously. In yield per tree Malling IX trees are falling behind the larger trees on the other stocks in the early bearing varieties, R. I. Greening, Melba and McIntosh. In the less precocious varieties, Delicious and Spy, the Malling IX trees are still well in the lead. Fruits from Malling IX trees have been very well coloured, at least part of which seems to be due to earlier maturity. Considering the heavy crops borne the size of the apples has been quite satisfactory.

TABLE 7.—GROWTH AND YIELD OF TREES ON MALLING IX

	Number of trees	Mean area of x-section of trunk, 1937 (sq. cms.)	Accumulated yield per tree up to 1937 (kgms.)
R. I Greening	3	38.5	56
Melba	6	22.2	40
Delicious	3	35.4	50
Spy	8	58.5	63
McIntosh	4	37.8	59

DISCUSSION

A careful examination of the growth and yield records in these apple stock trials shows that varieties differ in their response to stock effect. A stock that may be desirable for one variety for a certain purpose may not be the best one for another variety. The results at the East Malling (Eng.) Station as summarized in a recent paper by Hatton (1) demonstrate very well the varying effects of a certain stock on the scion varieties. To space trees of a certain combination in the orchard to the best advantage a grower ought to know the ultimate size of the tree, and it takes a long time to determine this.

Up to the present Malling II has proven to be a very satisfactory stock for McIntosh, and superior to Malling I, both with respect to growth and fruit production. In Massachusetts (3), on the other hand, three McIntosh trees on Malling II have been much inferior to McIntosh on Malling I stock. The latter stock also appears to be a very promising one for British Columbia conditions (2), but where there is low potassium availability, as in many Ontario orchards, it seems to be unwise to recommend it.

At least in the early years there seems to be but slight indication that the variability of apple trees can be reduced materially by the use of clonal stocks. The recent investigations of Shaw (3) and Spinks (4) point to the same conclusion. It appears that soil condition, physical and chemical, is a much more potent factor in creating variability than is stock.

SUMMARY

The Malling apple stock test orchard at the Ontario Horticultural Experiment Station has now completed its eighth year of growth. The stocks under test and their classifications are as follows: French Crab seedlings and Malling XVI, very vigorous; Malling I, vigorous; and Malling II, semi-dwarfing. Under the conditions of this trial the following conclusions may be drawn:

1. In three varieties French Crab seedling trees are larger than Malling XVI trees while the reverse is true with the other two varieties. Malling I trees are smaller than Malling II trees and there is no indication that the difference is becoming less.

2. Except in Melba, Malling II trees lead in fruit production on the per tree basis, and except in R. I. Greening, Malling XVI trees are the lowest in yield. On the basis of yield per 100 sq. cms. of trunk cross section Malling I and II trees have yielded considerably more fruit than French Crab and Malling XVI trees.

3. The larger crops on Malling I and II trees did not seem to react unfavourably on the colour of the fruit. There is a suggestion that Malling XVI trees may produce McIntosh apples of superior colour. In size of fruit there was no significant difference between the stocks.

4. Malling I trees appear to suffer most from potassium starvation and this may explain their slow growth as compared to Malling II trees.

5. There seems to be no reduction of variability in tree size by the use of clonal stocks in preference to seedling stocks but in fruit production the trees on clonal stocks have been slightly less variable.

6. Malling IX trees, not included in the above analysis, have been outstanding in precocity and heavy fruit production. The fruit matured earlier and was higher in colour than the fruit produced on any of the other stocks and the size of fruit was quite satisfactory.

ACKNOWLEDGMENT

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PRELIMINARY TESTS WITH PLANT HORMONES IN THE ROOTING OF GREENWOOD CUTTINGS[1]

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As early as 1882 Sachs (1) pointed out that certain responses in plants were probably caused by some "specific substances". By 1919 it was known that decapitated oat plant tips contained some substance which stimulated growth reaction in plants (2). In 1925, Van der Lek (3) claimed to have proved that the influence of buds on the rooting of cuttings might be due to plant hormones formed in them, and transferred to the basal end of the cuttings where they promoted root reaction. In 1928, Went (4) demonstrated that growth promoting substances could be isolated from decapitated oat tips.

Since that time much literature has been published concerning plant hormones, their movement within the plant, and reaction on various plant parts. Dr. Zimmerman and Hitchcock, since their first tests in 1933 (5), have discovered that many synthetic substances have the capacity to stimulate root growth when applied to various plant parts (6).

This research has been applied practically by many experimenters during the past two years in using these synthetic growth substances as aids in the propagation of plants by cuttings. Commercial preparations have been placed on the market with recommended treatments for various species. The horticultural press has been full of advertisements and statements concerning the use of these chemicals, some of which have been misleading because they have not been backed up by sufficient experimental work.

During the winters of 1935–36 and 1936–37, Ferguson carried on tests at the Horticultural Division of the Central Experimental Farm to determine the reactions of hardwood cuttings of apple to treatment with some of these growth substances.

Cuttings were treated with indolebutyric, indoleacetic, and indolepropionic acid both in water solution and lanolin paste but no positive reaction was obtained in either case.

The work described in this paper was carried on during the summer of 1937 to test the effectiveness of the better known commercial preparations in competition with solutions of indolebutyric acid prepared locally, and to determine if possible the optimum treatment to induce rooting of the various species and varieties tested, under conditions which obtain in the Canadian nursery trade.

EXPERIMENTAL

Materials

The following substances were tested in the strength indicated:

(a) Hortomone "A", a preparation of the Imperial Chemical Industries Limited, which contains naphthalene acetic acid as its active reagent.

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1 part to 480 tap water.
1 part to 320 tap water, which is the strength recommended by the manufacturer.
1 part to 160 tap water.

(b) Hormodin "A", a product of Merck & Co., which contains indolebutyric acid.

10 BTI units which is 1 part to 400 tap water.
20 BTI units which is 1 part to 200 tap water.
40 BTI units which is 1 part to 100 tap water.
80 BTI units which is 1 part to 50 tap water.

(c) Auxilin, a product of the Pennsylvania Chemical Co., which also depends on indolebutyric acid, was tried at the five strengths recommended by the manufacturer.

1 part to 800 of tap water.
1 part to 400 of tap water.
1 part to 200 of tap water.
1 part to 100 of tap water.
1 part to 50 of tap water.

(d) Indolebutyric acid, prepared locally, was used in the first test at the following strengths:

5 p.p.m. of tap water	80 p.p.m. of tap water
10 p.p.m. of tap water	120 p.p.m. of tap water
20 p.p.m. of tap water	160 p.p.m. of tap water
40 p.p.m. of tap water	200 p.p.m. of tap water

In subsequent tests this was reduced to:

10 p.p.m. of tap water	80 p.p.m. of tap water
20 p.p.m. of tap water	100 p.p.m. of tap water
40 p.p.m. of tap water	

A 1% stock solution of the crystals was made in alcohol, and from this fresh water solutions were prepared each day to the required strengths.

The species and varieties varied somewhat in the different tests:

Sand,

Syringa vulgaris Peggy
Syringa vulgaris Patricia
Syringa Prestoniae Calphurnia
Syringa Prestoniae Jessica
Malus Antonovka
Malus Athabaska
Hydrangea paniculata
Forsythia intermedia

Sand and peat,

Syringa vulgaris Norah
Syringa vulgaris Grace
Syringa vulgaris Muriel
Syringa vulgaris Maureen
Syringa Prestoniae Celia
Syringa Prestoniae Virgilia
Malus Erie
Malus Hibernal
Rose Agnes
Rose Ellen Poulsen

Method

Chemical Treatment

Cuttings were taken at three different periods, mid June, late July, and early August. All were of the type most approved for the species by

the nursery trade; *i.e.*, some with a heel of last year's wood, some without, and from 2 to 4 inches long. Cuttings were tied in bundles of five, which was the unit of treatment, and stood with their basal ends in the various solutions to a depth of $\frac{1}{2}$ inch to $\frac{3}{4}$ inch. The time of treatment varied from 6 to 48 hours, but the majority of cuttings were treated for 24 hours, as this period fits best into a daily routine of work.

Cultural Treatment

All cuttings were planted out of doors in cold frames with cotton shades on sides, and four feet above the top of the frame. Cuttings were syringed with water at least twice a day to keep up humidity and were left in the frame for a sufficient length of time to root the best treatments sufficiently for potting. This period of course varied with the different species.

In the first and third tests, some cuttings were planted in straight sand, and some in 50–50 sand and peat mixture. As lilacs predominated, all cuttings in these tests were kept closely covered with glass sash for the first four weeks, receiving only a little ventilation at noon.

In the second test, all cuttings were planted in sand and peat mixture, and some species which require more free circulation of air such as *Hydrangea paniculata*, were not covered with sash.

During the first test, records were taken at 9 a.m. each morning, the averages being as follows:

Soil temperature	70.3
Air temperature	72.1
Humidity	84.4

RESULTS

The following tables show the percentage of cuttings which rooted under each treatment, together with the length of time cuttings were left in the frame. Only those treatments which proved reasonably effective are indicated. In many cases cuttings had callused at the time results were checked and some of these rooted later. These are not shown, as the object of the work was to determine the optimum treatment for producing rooted plants.

Effectiveness of Treatment

DISCUSSION

While the Tables 1 and 2 show what seem to be rather low percentages in a number of instances, it must be kept in mind that under normal conditions our average for the species and varieties tested is much lower, and the length of time required for rooting much longer. Thorpe of the Horticultural Division, C.E.F., in 1935–36 rooted only 30% with *Syringa Calphurnia*, and 12% with *Syringa vulgaris* varieties when the cuttings remained in the frame for three months. According to the tables, *Syringa Calphurnia* rooted 80% at 80 ppm. of indolebutyric acid in 45 days, and *Syringa vulgaris* varieties rooted 40% at the same strength, which seems to be the best for lilacs throughout the tests. In 1936, the writer succeeded in rooting 60% of *Taxus cuspidata* cuttings after six months in the frame, whereas with 80 ppm. indolebutyric acid the same result took only 46 days.

All commercial preparations produced positive results at the strengths recommended by the manufacturers, though too much variation occurred to be able to recommend one treatment only for each species.

TABLE 1.

Plant name	No. of days	Check	Hortomone A			Hormodin A				Indolebutyric acid				
			1–480	1–320	1–160	10 unit	20 unit	40 unit	80 unit	10 ppm.	20 ppm.	40 ppm.	80 ppm.	120 ppm.
TEST I														
Sand,														
Syringa vulg. Peggy	45	0	*	40	20	–	20	40	20	–	*	20	40	–
Syringa vulg. Patricia	45	0	*	20	*	–	*	20	*	–	–	*	20	–
Syringa Prestoniae Calphurnia	43	20	20	60	40	*	20	60	20	20	*	60	80	20
Syringa Prestoniae Jessica	43	0	*	20	*	–	*	20	–	–	*	20	20	–
Malus Antonovka	41	All malus cuttings dead.												
Malus Athabasca	41													
Hydrangea paniculata	35	20	80	60	–	80	60	–	–	40	80	40	–	–
Forsythia intermedia	33	0	20	20	–	–	20	–	–	–	–	20	–	–
Peat and Sand,														
Syringa vulg. Norah	45	0	0	20	*	–	*	20	*	–	–	*	20	20
Suringa vulg. Grace	44	0	0	40	*	0	*	20	*	–	*	*	20	20
Syringa vulg. Muriel	45	0	*	20	20	–	*	20	*	–	–	*	20	40
Syringa vulg. Maureen	44	0	*	40	20	–	–	20	*	–	–	*	40	20
Vulgaris Prest. Celia	43	0	*	40	20	0	*	40	20	0	–	*	40	20
Syringa Prest. Vigilia	43	0	*	20	*	*	*	20	–	*	*	20	–	–
Malus Erie	39	All malus cuttings dead.												
Malus Hibernal	39													

* Cuttings in more advanced condition than check unit though none rooted.

– Cuttings dead or damaged.

TABLE 2.

Plant name	No. of days	Check	Hortomone A			Hormodin A				Indolebutyric acid					Auxilin				
			1–480	1–320	1–160	10 unit	20 unit	40 unit	80 unit	10 ppm.	20 ppm.	40 ppm.	80 ppm.	100 ppm.	1	2	3	4	5
TEST II																			
Sand and peat																			
Hydrangea paniculata	30	40	60	40	–	100	40	–	–	20	100	40	–	–	20	–	20	40	80
Rose Sylvia	36	0	40	–	–	40	20	–	–	*	20	–	–	–	60	20	–	–	–
Rose Ellen Poulsen	36	0	20	20	–	40	20	–	–	*	20	40	–	–	20	20	20	–	–
Syringa Prest. Virgilia	45	0	–	20	20	*	*	40	20	–	*	20	40	20	*	*	–	20	40
Syringa vulg. Thumberg	45	0	*	20	*	–	*	60	20	–	*	*	40	20	*	*	*	*	40
Forsythia intermedia	45	0	*	40	20	*	–	60	20	–	20	60	20	–	–	–	20	100	20
Viburnam Lantana	45	0	0	20	0	–	*	20	–	–	–	20	*	–	–	–	–	–	–
Malus floribunda	45	0	0	20	All others dead.														
Thuja occ. Wareana	52	0	0	20	60	0	20	100	40	0	–	*	20	80	0	–	*	20	50
Thuja occ. pyramidalis	53	0	0	*	40	0	*	20	60	–	–	0	40	80	0	*	40	20	20
Juniperus sabina	52	0	0	*	40	0	*	20	40	0	0	*	20	60	0	0	*	60	*
Taxus cuspidata	53	0	0	20	40	0	20	60	20	0	–	40	60	20	0	0	0	*	*
TEST III																			
Sand																			
Syringa Prest. Miranda	46	20	20	60	20	*	60	20	–	60	40	–	–	–	*	*	60	20	–
Syringa vulg. Thumberg	46	20	40	20	–	20	*	*	*	20	*	*	*	*	40	20	*	*	*
Thuja occidentalis	43	0	0	20	0	0	20	*	0	0	0	20	20	0	0	*	20	*	0
Malus Patton Greening	46	*	*	*	–	*	*	–	–	*	*	–	–	–	*	*	–	–	–
Peat and sand																			
Syringa Prest. Miranda	46	20	*	60	*	*	40	40	–	*	20	60	20	–	*	–	20	40	20
Syringa vulg. Thumberg	46	20	20	40	20	*	40	*	*	20	60	20	–	–	20	40	*	–	–
Thuja occidentalis	43	0	*	40	*	0	20	0	0	0	*	40	40	0	0	40	0	0	–
Malus Patton Greening	46	*	0	*	*	*	*	0	–	*	*	*	–	–	*	*	*	0	–

* Cuttings in more advanced condition than check unit though none rooted.

– Cuttings dead or damaged.

FIGURE 1. *Syringa Calphurnia.* Left to right: check, 10 ppm. 20%; 40 ppm. 60%; 80 ppm. 80%; 120 ppm. 20%; 160 ppm. 40%; bases rotted off.

FIGURE 2. *Hydrangea paniculata.* Top untreated, bottom 10 BTI units Hormodin.

In general, the roots produced by Hortomone A (naphthalene acetic acid) were stockier than the others, though results were not quite so high as a rule.

From the tables we can readily see the comparative strengths of the products containing indolebutyric acid when they are compared with the results obtained by treatment with the straight chemical. (It is quite evident from the consistency of the results that one BTI unit (Boyce Thompson Institute) is equal to 2 ppm.)

Root Development

There seems to be no direct progressive relationship between root development and concentration of chemical except within the narrow limits of the effective zone. In some cases where checks and cuttings treated with weak solutions remained healthy and rooting occurred at fairly high concentrations, there seemed to be an intermediate concentration which caused damage or death. Very strong concentrations 120 to 200 ppm. indolebutyric acid caused splitting and burning with consequent death in many cases. Often cuttings damaged in this way rooted from higher up the stem even though the base of the cutting rotted off. This was particularly the case with *Hydrangea* and other softer wooded plants.

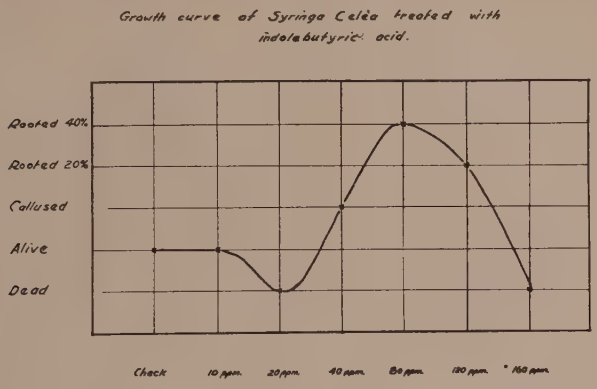

FIGURE 3. Growth curve of *Syringia celia* treated with indolebutyric acid.

These points are more readily seen in Figure 3 which represents the results with *Syringa* Celia.

The quality of root was much stockier and of a lighter colour and the number of roots much higher than in normally rooted cuttings. This was particularly the case in the higher concentrations.

Absorption and Its Effect

Apparently the quantity of the solution absorbed, as well as the concentration, has a large influence on the rooting. In the first test *Syringa* Virgilia was treated in a window where it received sunlight during the morning hours and obviously received an overdose of the chemical, though *Syringa* Celia rooted quite well at the same concentrations.

During the second test, records were kept at the time of treatment, which showed that under normal light from a northeast window the average cutting of lilac or apple absorbed 2.4 cc. of solution in 24 hours, while

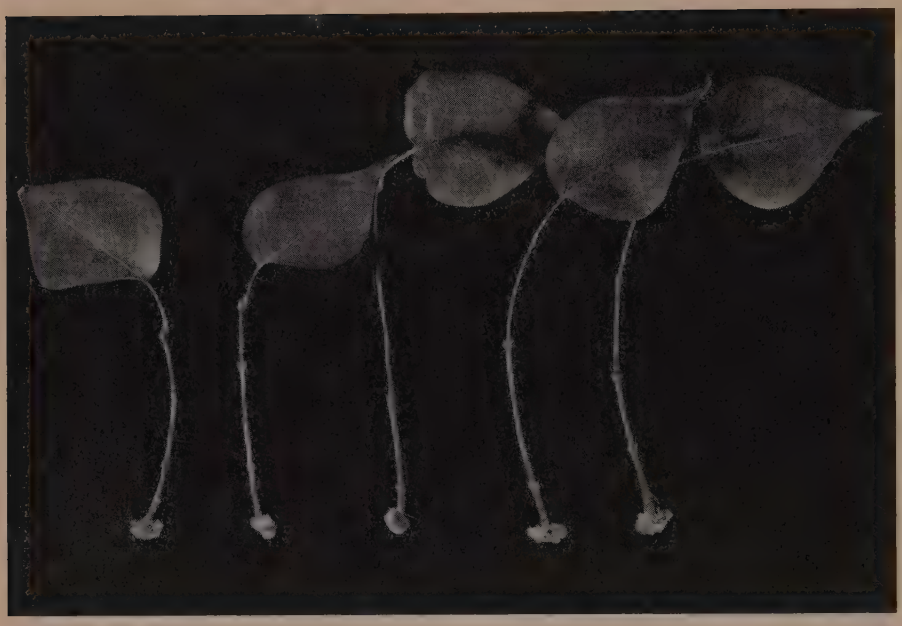

FIGURE 4. Lilac cuttings showing enlarged cuttings.

cuttings exposed to sunshine during the morning hours and skylight for the remainder absorbed 4.9 cc. In coniferous cuttings the rate of absorption was 0.5 cc.

As the rate of absorption will also vary with the temperature and humidity of the room in which the cuttings are treated, all these factors of light, heat, and humidity will have a bearing on the optimum treatment.

Sand vs. Peat

Under normal conditions, lilacs root more readily in a sand-peat mixture. From the above result the reverse would seem to be the case when hormones are used. Also from the tables for Test III, it would appear that in the case of *Thuja*, which normally has a very strong preference for peat, lower concentrations are necessary where sand is the medium than where peat and sand is used. This would indicate that the pH content is also a factor influencing the optimum treatment.

In lilacs, the majority of cuttings which formed callus in sand rooted well, while in peat and sand mixture more cuttings callused but many failed to root and simply increased the amount of callus over a period of three months.

CONCLUSIONS

(1) The plant hormones tested are of value to the nursery trade in hastening the rooting of greenwood cuttings and increasing the percentage rooted.

(2) Species and varieties reacted positively to varying concentrations so that an optimum treatment must be found for each species.

(3) This optimum treatment will be influenced by the light, temperature, and humidity conditions under which the cuttings are treated; by

the degree of ripeness of the wood and by the pH of the medium in which they are planted.

(4) The optimum treatment for the species tested is approximately as follows in terms of indolebutyric acid:

Syringa vulgaris and *Prestoniae* varieties	80 ppm.
Hydrangea paniculata	20 ppm.
Forsythia intermedia	40 ppm.
Roses	20–40 ppm.
Taxus cuspidata	80 ppm.
Thuja occidentalis and varieties	100 ppm.
Juniperus sabina	80 ppm.

(5) Apples of the varieties tried do not respond readily.

From these conclusions it will be seen that a great deal of work must be done before definite treatments can be recommended with any degree of safety. For the present the grower should try two or three strengths ranging around those mentioned above.

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BORON DEFICIENCY IN CAULIFLOWER[1]

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Many workers in different parts of the world have shown that the element boron has a very definite place in plant nutrition. A deficiency of this element has produced physiological diseases of grave economic importance in some of our cultivated plants. In recent years it has been found that applications of boron either as boric acid or borax will prevent such important disorders as brownheart of turnips, and cork and drought spot of apples.

Deficiencies of this element may cause disorders which have not been recognized from symptoms evidenced in other plants.

In so far as possible it is one of the purposes of this laboratory not only to find the causes of nutritional disorders and means of their prevention, but also to anticipate such disorders. An experiment in this connection has brought to light very interesting information on the effect of boron deficiency in cauliflower plants.

PROCEDURE

Cauliflower seed, variety Early Snowball, were germinated in greenhouse soil. When large enough they were pricked out into 4-inch pots containing ground, washed sandstone. The plants were held in these pots until the root system was large enough to permit transferring to 2-gallon glazed jars containing ground, washed sandstone.

The nutrient solution supplied to these plants was based on that used by Hill and Grant (2). The amount of boric acid stock solution (1 gm. H_3BO_3 in 1000 cc. water) added to the feeding solution varied with the treatment from 0 cc. to 23 cc. The feeding solution was applied at the rate of 200 cc. weekly per plant. This was increased to 300 cc. as the amount of growth increased.

Parts per million of the elements in the feeding solution were:

N	P	K	Mg	Ca	S	Cl	Fe	Mn
1553	123.7	929.4	96.4	400	127	352	33.04	0.29

The concentrations of boron in the feeding solution according to the treatment were, 0, 0.25, 0.5, 0.75, 1.0, 1.5 and 2.0 parts per million.

RESULTS

The plants under all the treatments continued to grow in a normal and healthy fashion until the curd began to show. From this time on the differences between the boron deficient plants and those receiving boron became increasingly more marked.

On the boron deficient plants the smaller leaves, surrounding the curd became deformed and twisted with the characteristic stunted appearance of boron-starved plants. This condition gradually became worse

[1] Contribution No. 498 from the Division of Horticulture, Dominion Experimental Farms System

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until the condition shown in Figure 1-B was reached. Some of these smaller leaves became so deformed and stunted that they consisted of little more than the main stalk. From the time the curd appeared it remained very small, almost in a vestigial state. Very little of the usual branching of the curd took place and no flowers developed. The top of the curd remained brown in colour from the time of its appearance.

The boron-fed plants all showed normal growth regardless of the concentration of boron in the feeding solution. Figure 1-A shows a normal plant on which the leaves and curd are healthy in every respect. This plant received a concentration of 0.25 p.p.m. of boron in the feeding solution.

A B

Figure 1. A. Plant fed 0.25 p.p.m. boron in feeding solution. B. Plant fed 0 p.p.m. boron in feeding solution.

When these plants were cut through from top to bottom the browning on the surface of the boron deficient curd was found to extend down into the flesh and even into the stalk as seen in Figure 2-A. These internal areas presented much the same brownish, water-soaked appearance as the areas denoting brownheart in turnip roots. Figure 2-B illustrates the normal, healthy development secured when the plants receive 0.25 p.p.m. of boron in the feeding solution.

The effect boron has had in producing large, healthy white curds as contrasted with the small, brown curds produced by boron deficient plants is noteworthy. Thus, applications of boron to the soil may prevent the formation of brown coloured cauliflower curds which were so prevalent in Eastern Ontario in 1937.

50928—4

A B

FIGURE 2. A. Section through plant receiving 0 p.p.m. boron. B. Section through plant receiving 0.25 p.p.m. boron.

CONCLUSIONS

Boron is essential for the normal, healthy growth of cauliflower.

Insufficient boron will cause a stunting and deformation of the leaves immediately surrounding the curd.

Insufficient boron will result in the production of smaller curds, incompletely developed and brown in colour.

Insufficient boron will result in the appearance of brownish, water-soaked areas in the flesh and stalk.

A concentration of 0.25 p.p.m. of boron in the feeding solution applied to plants growing in sandstone is sufficient to produce normal plants.

APPENDIX

Subsequent to arriving at the above conclusions, the paper by Dearborn, Thompson and Raleigh (1) reporting similar results was received.

REFERENCES

1. Dearborn, C. H., Thompson, H. C., and Raleigh, G. J. Cauliflower browning resulting from a deficiency of boron. Department of Vegetable Crops, Cornell University, Ithaca, N.Y. Paper 161. 1937.

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LES FERMENTS

APPLICATION DE LEUR SPÉCIFICITÉ À LA RECHERCHE DES OSIDES DANS LES PLANTES

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I.—NOTIONS GÉNÉRALES SUR LES FERMENTS

C'est au début du XIXième siècle, à la suite des recherches de Dubrunfaut et de Mitscherlich que furent découvertes des substances spéciales qui reçurent des dénominations différentes suivant les auteurs: Kühne leur donna le nom d'enzymes, alors qu'en France Payer et Persoz les dénommaient diastases; d'autres enfin recoururent au terme de ferments solubles par opposition au terme de ferments figurés, tout en faisant remarquer qu'à leur avis il n'y avait pas lieu d'établir cette distinction puisque les ferments solubles possédaient les mêmes propriétés que les ferments figurés, et que par conséquent une même désignation pouvait s'appliquer aux deux catégories.

Cette hypothèse fut reconnue sans fondement à la suite des recherches de Büchner sur la levure de bière. Cet auteur montra que la levure de bière (ferment figuré) ne provoquait le dédoublement du sucrose en glucose et lévulose que par la sécrétion d'une substance spéciale (ferment soluble) appelée invertine ou sucrase. En effet grâce à l'action de la presse hydraulique il réussit à extraire de cette levure un liquide qui mis en présence de saccharose provoquait aussi la transformation du sucre. Ce n'est donc pas la cellule elle-même qui provoque cette réaction fermentaire mais les produits qu'elle secrète; elle se comporte d'une façon identique aux cellules de l'estomac qui secrètent de la pepsine. Cette distinction entre les ferments est donc nécessaire.

Dans les années qui suivirent, on découvrit grand nombre de diastases tant dans le règne animal que dans le végétal. Si bien qu'on en tira la loi générale suivante: chez les animaux elles président aux phénomènes de dégradation des aliments et à leur assimilation (Cl. Bernard), et chez les végétaux elles déterminent les réactions de synthèse (Bourquelot) pour la mise en réserve des principes immédiats élaborés. C'est ce qui fit dire à Cl. Bernard que les ferments doivent contenir le secret de la vie, sans être toute la vie, car tandis que l'anesthésie supprime les sensations, le mouvement, elle reste sans action sur les processus fermentaires de métabolisme.

Ces manières de voir ne furent pas admises entièrement par nombre de biologistes, et Colin notamment s'exprime ainsi: on ne peut définir la vie comme une source de phénomènes diastasiques. Un petit nombre seulement de réactions intracellulaires relèvent d'enzymes authentiques; ce sont surtout des réactions de dégradation; elles s'effectuent tout aussi bien in vitro et ne dépendent de la vie qu'en raison des ferments qui les provoquent. Il en va tout autrement des opérations de synthèse; celles-ci sont inséparables de la vie et rien n'autorise à les assimiler purement et simplement à des phénomènes diastasiques.

Nature des Ferments

Deux théories s'opposent: l'une qui considère la diastase comme une substance chimique définie (diastase substance), l'autre qui ne considère la diastase que comme une source d'énergie (diastase propriété). Malgré toutes les recherches et les faits en faveur de l'une ou de l'autre, la question reste encore toute entière.

Les partisans de la première théorie considèrant la diastase comme un corps défini, voulurent employer pour sa purification et son isolement les méthodes chimiques habituelles. Ce n'est qu'en 1928 que Sumner réussit à isoler pour la première fois une diastase, l'uréase, sous une forme cristallisée. D'après cet auteur, il s'agirait d'une globuline dont l'activité s'accroit par cristallisation successive. Plus tard, en 1929 Northrop préparait de la même façon de la pepsine cristallisée.

Mais est-ce que ces découvertes permettent de généraliser? L'uréase et la pepsine faisant partie des protéases, pourra-t-on juger de la même façon les glucidases ou les lipases? Willstatter chercha à résoudre la question, mais toutes ses tentatives ont échoué car au fur et à mesure que la purification s'avancait les propriétés des diastases allaient en s'évanouissant pour disparaître complètement.

Il y a d'ailleurs là une analogie avec les colloïdes, et c'est pourquoi on a classé les ferments parmi les substances colloïdales. Considérons le trisulfure d'arsénic As^2S^3; ce corps à l'état colloïdal présente la formule de masse variable As^2S^3, nSH^2 où nSH^2 représente une impureté nécessaire pour que le corps prenne et garde l'état colloïdal. Si on cherche à le purifier, et par conséquent à ôter nSH^2, le corps perd son état particulier. C'est identique à ce qui se passe pour les diastases. Il suffit de se rapporter aux belles recherches de G. Bertrand sur la laccase contenue dans le latex de l'arbre à laque. Elle serait constituée par une substance organique sur laquelle serait fixées par adsorption des micelles de manganèse; cet ensemble constitue le système actif. Otons l'impureté constituée par le manganèse, et aussitôt les propriétés oxydantes disparaissent. Nous arrivons ainsi à la théorie de la diastase propriété d'après laquelle les substances minérales à l'état de très fines particules étant fixées à la surface de la molécule détermineraient dans le système un déséquilibre ionique. Cette action des micelles sur les électrolytes prévoit immédiatement la possibilité de l'utilisation d'une certaine quantité de l'énergie intramoléculaire, et l'on peut s'expliquer de cette façon la puissance des phénomènes diastasiques.

Si l'on compare l'action des diastases à celle des catalyseurs, on constate une grande analogie. Les métaux colloïdaux par exemple, présentent des conditions d'action qui ressemblent étrangement à celles des ferments: l'activité des métaux colloïdaux est détruite à 100°, ils agissent à des pH déterminés, ils peuvent être paralysés par certains toxiques comme l'acide cyanhydrique ou le sublimé.

On sait que des catalyseurs sont des corps qui modifient la vitesse d'une réaction sans être détruits. C'est aussi le cas des diastases. Un grand nombre de réactions fermentaires peuvent être accomplies à l'aide de catalyseurs minéraux: ainsi un protide peut être dégradé à l'état de peptones à 40° sous l'action de l'acide chlorhydrique fort, ou à 100° sous l'action de HCl étendu. Les protéases accomplissent ces mêmes réactions

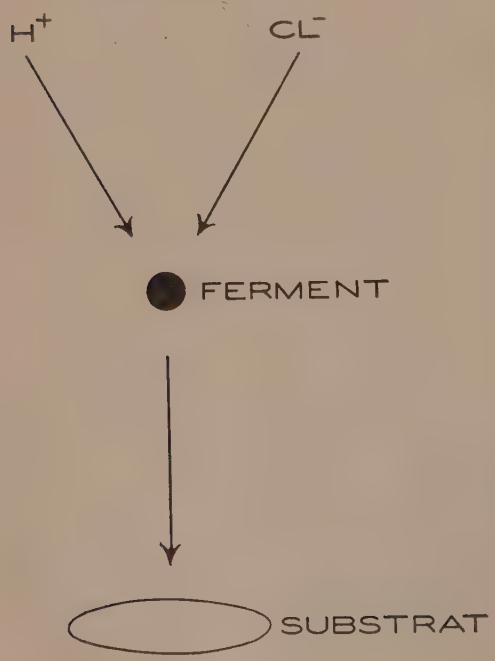
aussi rapidement à la température du corps et dans des conditions compatibles avec la vie des cellules. Cette action plus douce et aussi rapide que les méthodes chimiques montre la valeur des diastases comme agents du chimisme cellulaire. En se basant sur ces propriétés Bourquelot eut l'idée d'utiliser ces agents comme réactifs de laboratoire et ainsi imagina les méthodes biochimiques. Ses recherches l'amenèrent à étudier la réversibilité des réactions et à considérer les diastases comme des catalyseurs susceptibles de détruire ou de construire suivant les nécessités et les conditions de la vie: chez les plantes, elles joueraient un rôle antitoxique en éliminant les composés dangereux ou en excédant (Goris).

Cette théorie de Bourquelot sur les synthèses et les réactions réversibles reçut récemment une confirmation brillante lors de la découverte en 1925 par Wattiez du méthylglucoside β dans les dipsacées. Bourquelot étant arrivé à faire in vitro cet oside en utilisant les méthodes fermentaires, estima qu'on devait le rencontrer dans le monde végétal; c'est ce qui eut lieu 20 ans plus tard.

D'après ce que nous venons de voir la définition la plus exacte des diastases serait la suivante: des catalyseurs biochimiques solubles, colloïdaux, extraits des tissus vivants (Wattiez et Sternon).

Conditions d'action et mode d'action des ferments

Toute action fermentaire nécessite la présence d'eau, un certain pH du milieu, et la présence de deux substances appelées co-ferment et ferment. D'après Ambard, une substance dite co-ferment, par elle-même inactive confère à une autre substance dite ferment, par elle-même également inactive, la propriété de transformer une tierce substance. Pour analyser le mécanisme des actions diastasiques reportons-nous à un travail récent de cet auteur sur l'amylase.



Une réaction fermentaire hydrolysante peut se décomposer en 3 processus: la fixation du co-ferment sur le ferment, la fixation du complexe coferment-ferment sur le substrat et l'hydrolyse proprement dite du substrat.

D'après la reproduction ci-dessus, on comprend que l'hydrolyse est une résultante de deux facteurs qui peuvent varier indépendamment l'un de l'autre. Ambard a montré que pour l'amylase, il existe un co-ferment formé d'un ion H et d'un anion monovalent, et qu'en l'absence de co-ferment, l'amylase ne s'unit pas avec l'amidon et par conséquent l'hydrolyse ne peut avoir lieu. Ainsi une solution d'amylase active devient in-

active si on élimine complètement les electrolytes par dialyse, toutefois la réactivation peut être réalisée si on ajoute NaCl.

En résumé, il semble qu'à l'heure actuelle on doive considérer un système fermentaire comme formé de 3 constituants: des electrolytes, un support colloïdal et enfin le groupe actif ou diastase proprement dite.

Propriétés des ferments

Ils se dissolvent dans l'eau et la glycérine, tandis que l'alcool les précipite de leur solution. C'est sur ce principe que sont basées toutes les méthodes de préparation et d'extraction des ferments.

Si l'on considère après une action fermentaire, la quantité de diastase qui a agi et la quantité des produits de transformation, on est frappé par la disproportion entre l'effet et la cause. Ainsi la présure du suc gastrique est capable de coaguler de 400.000 à 800.000 fois son poids de caséine (Hammarsten).

Les diastases ne se détruisent pas en agissant, une masse donnée de diastase pouvant, à condition d'éliminer les produits formés, transformer une quantité à peu près illimitée de substance. Si nous mettons des ferments lactiques en présence de lait, aussitôt, si les conditions sont favorables, la vitesse de réaction atteindra une certaine valeur, passera par un maximum, puis diminuera pour atteindre à la fin une valeur nulle. Ce fait n'est pas dû à une destruction des ferments, mais est causé par un excès d'acidité dû à l'acide lactique; en effet si l'on neutralise cet acide ou si on l'isole, on constate que les réactions de transformation recommencent, s'il existe encore du lactose dans le milieu.

La température joue un rôle important dans les actions fermentaires. A 0° l'activité diastasique est suspendue et les basses températures ne les détruisent pas; à partir de 0° l'activité croit pour passer par un maximum pour une température optima comprise entre 40 et 55°. Vers 60 ou 70° en milieu liquide les diastases sont détruites, alors qu'en milieu sec elles peuvent résister jusqu'à 100°.

Les antiseptiques qui s'opposent à la multiplication cellulaire ont aussi une action quoiqu'à un degré moindre sur les ferments solubles. Ces derniers sont beaucoup plus résistants que les éléments cellulaires; il ne s'agit là que d'une question de proportion qui est utilisée lorsqu'on veut arrêter une multiplication cellulaire sans entraver une action fermentaire, et dans ce cas, il suffit de choisir une dose convenable d'antiseptique.

Spécificité des ferments

Nous avons préféré traiter cette question séparément, parce que c'est sur cette propriété que sont basées les méthodes biochimiques.

La spécificité des ferments a été mise en évidence depuis longtemps, mais de nos jours elle semble très discutée. Si l'on considère les grands groupes tels que les glucidases, les protéases, les lipases, on n'a aucune peine à admettre la spécificité de chacun d'eux, mais dès que l'on examine séparément les diastases d'un même groupe, la difficulté apparaît, et cette difficulté est d'autant plus grande que pour les classer on ne peut se baser sur leur composition qui nous est inconnue. Les méthodes employées pour étudier la spécificité sont au nombre de trois: 1°—La méthode comparative qui étudie parallèlement les diastases provenant de plusieurs

sources sur un même corps. La trypsine (protéase animale) et la papaïne (protéase végétale) possèdent la même action sur les protides, mais diffèrent l'une de l'autre, car la première n'agit qu'en milieu alcalin et la deuxième qu'en milieu acide. 2°—La méthode de destruction qui consiste à détruire par la chaleur ou les antiseptiques certaines diastases contenues dans un milieu fermentaire. De cette façon Bridel et Arnold détruise la sucrase qui se trouve toujours dans l'émulsine des amandes amères, en traitant le complexe fermentaire par l'alcool fort. 3°—La méthode basée sur les vitesses de réaction.

On connaît l'expression de Fischer qui assimilait l'action d'une diastase sur un corps à une clef s'adaptant sur une serrure. C'est d'ailleurs sur la spécificité que cet auteur s'est basé pour classer les osides soit dans la série α soit dans la série β, car il a vu que les osides α étaient dédoublables par la levure et les osides β par l'émulsine. Ainsi la spécificité absolue n'existe pas: Kühne avait déjà constaté que la β glucosiadase dédouble non seulement le β méthylglucoside, mais aussi le prunasoside, le salicoside, l'arbutoside, et Willstatter avait prouvé que la levure attaque aussi bien le maltose que l'α méthylglucoside et que l'α phénylglucoside.

Il n'existerait donc pas de spécificité absolue d'espèce mais une spécificité de groupes de fermentation comprenant des corps qui présentent des analogies du point de vue constitution stéréochimique.

A quoi serait dû la spécificité? Certains auteurs admettent que les diastases présentent des différences de structure analogues à celles qui existent pour les glucides des séries α et β (Fischer et Schoen). D'après Kopaczewski la spécificité serait due, sinon exclusivement, tout au moins en grande partie, à la présence d'ions fixés sur la micelle colloïdale.

Pour nous résumer sur cette question qu'il nous suffise de citer l'avis de G. Bertrand: Le réactif diastasique dont l'action paraissait d'une spécificité absolue quand on se bornait à l'étudier dans ses rapports avec le principe immédiat attaquable, à côté duquel on l'avait découvert, n'a plus qu'une action spécifique relative quand on vient à reconnaître la fonction ou la structure chimique qui rendait le principe immédiat tributaire de son action.

II.—APPLICATION DE LA SPÉCIFICITÉ. MÉTHODES BIOCHIMIQUES

C'est en se basant sur le fait que les diastases s'attaquent de préférence à certains composés, que Bourquelot eut l'idée dès 1906 de les utiliser dans la recherche des glucosides dans les plantes à la place des réactifs chimiques dont l'action trop brutale peut décomposer et altérer les corps mis en liberté. Pour montrer l'importance de la découverte de Bourquelot, il suffira de rappeler brièvement l'état de nos connaissances au début du XIXième siècle.

A cette époque un pharmacien Derosne avait réussi à extraire de l'opium, un alcaloïde: la morphine. Le procédé général d'extraction fut employé par nombre de savants dans le but de connaître les principes actifs des plantes en usage dans la pharmacopée. Mais qu'elle ne fut pas leur étonnement en s'aperçevant que nombre de plantes que l'on utilisait dans telle ou telle maladie ne renfermait aucun principe isolable par la méthode de Dérosne. On en conclut qu'elles n'avaient aucun pouvoir thérapeutique et on les délaissa jusqu'en 1829 où un autre pharmacien

réussit à isoler de l'écorce de saule un principe tout différent de ceux qu'on avait extrait jusqu'alors: la salicine. Contrairement aux alcaloïdes, la salicine était incapable de donner des sels avec les acides, et sous l'influence de l'acide sulfurique elle était décomposée en donnant naissance à un sucre réducteur que l'on pensait toujours être du glucose d'où le nom de glucosides qui fut attribué à ce nouveau groupe de corps. En 1901 on connaissait déjà 14 glucosides, sans que l'on ait trouvé aucune méthode générale pour les déceler et les identifier. En 1906 Bourquelot en se basant sur ses recherches sur l'émulsine et l'invertine, songea à les utiliser pour reconnaître la présence des holosides et des hétérosides; les méthodes biochimiques étaient découvertes. Le procédé peut se résumer dans la combinaison d'un examen au polarimètre et d'un dosage des substances réductrices. Les deux ferments qu'il utilisa furent l'invertine et l'émulsine. L'invertine de la levure paraissait ne s'attaquer qu'au saccharose libre ou combiné. L'émulsine n'agissait que sur les hétérosides lévogyres et le seul produit actif sur la lumière polarisée qu'elle mettait en liberté était le glucose, corps dextrogyre.

Voyons en détail l'action de ces deux ferments:

1° Méthode à l'invertine.

L'invertine ou sucrase agit sur tous les corps dextrogyres et non réducteurs, diholosides, triholosides, tetraholosides, en libérant une molécule de fructose aux dépens du saccharose libre ou combiné, et en déterminant un changement de rotation vers la gauche. En même temps le liquide devient réducteur.

Voici, d'après A. Meunier, des schémas qui feront comprendre l'action de la sucrase.

$$\text{Saccharose} + H^2O = \underbrace{\textit{fructose} + \text{glucose}}_{\text{saccharose}}$$

$$\text{Raffinose} + H^2O = \textit{fructose} + \underbrace{\text{glucose} + \text{galactose}}_{\text{mélibiose}}$$

$$\text{Stachyose} + H^2O = \textit{fructose} + \underbrace{\text{glucose} + \text{galactose} + \text{galactose}}_{\text{manninotriose}}$$

Par cette méthode Bourquelot a imaginé un indice caractéristique pour chaque oside, il l'a appelé Indice enzymolytique (q): c'est le nombre de milligrammes de produits réducteurs exprimés en glucose, formés dans 100cc de solution sous l'influence de l'invertine pour un changement de déviation de 1° observé au tube de 2 décimètres. Cet indice qui semblait spécifique au début, s'est montré en défaut en 1920 où l'on constata que l'invertine renfermait des ferments capables d'hydrolyser certains fructoholosides et même un glucoholoside, le laminaroholoside. Malgré ces indices anormaux qui ne se rencontrent que dans certaines familles végétales, la méthode n'a pas perdue de sa valeur.

2°—Méthode à l'émulsine

L'émulsine n'est pas un ferment, mais un mélange de plusieurs ferments spécifiques des glucosides β. Son action consiste à mettre en liberté du glucose dextrogyre et à amener un changement de rotation vers la

droite. On mesure la quantité de matières réductrices formées et le changement de rotation. Il existe aussi pour l'émulsine un indice enzymolytique.

Pour faire comprendre plus facilement l'importance de la méthode, nous allons montrer comment peut se faire l'identification de l'oside contenu dans les feuilles de laurier-cerise (Wattiez et Sternon).

On prend tout d'abord la déviation polarimètrique du liquide d'extraction défèqué; supposons que l'on trouve + 2°. Dosons les sucres réducteurs, soit 0, 50gr%.

A une autre quantité de liquide d'extraction, on ajoute de l'invertine, puis après un séjour de 2 jours à l'étuve, on fait une nouvelle lecture polarimétrique, soit 0°.

La différence entre les deux lectures est de + 2° − 0° = 2°.

On dose dans ce même liquide les sucres, soit 1,706%. La différence entre les deux dosages est; 1,706 − 0,500 = 1,206gr %.

Connaissant les indices enzymolytiques des principaux osides, on peut savoir quel sucre a participé au dédoublement. Dans le cas qui nous intéresse c'est le saccharose dont l'indice est de 603 mmgr. En effet pour un retour de 2° la quantité de sucres réducteurs qui s'est formée devrait être de 0,603 × 2 = 1,206 c'est-à-dire le chiffre que nous avons trouvé plus haut.

On détruit ensuite l'invertine par la chaleur, puis on ajoute de l'émulsine et après un séjour de deux jours à l'étuve, on examine le liquide. A l'examen polarimètrique, on a une déviation de + 3°. D'où une augmentation de + 3° − 0° = 3°.

Le dosage des sucres réducteurs donne 2,283gr, d'où une différence de 2,283 − 1,206 = 1,077, augmentation qui correspond à un retour de 3° polarimétriques. L'indice enzymolytique sera donc de $\frac{1,077}{3}$ = 0,359. Ce chiffre correspond à l'indice du prulaurasoside, oside contenu dans les feuilles du laurier-cerise.

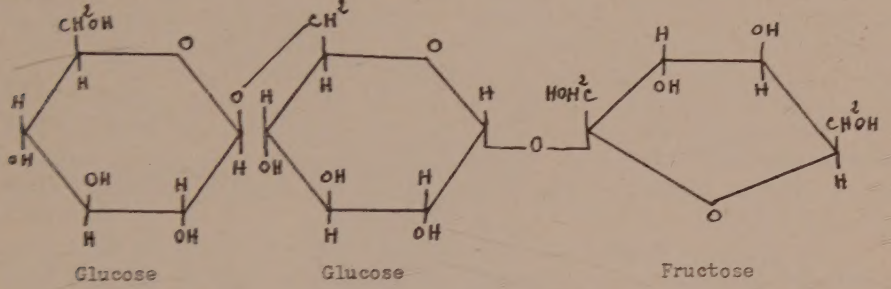
Ainsi en combinant l'action de l'invertine et de l'émulsine, on peut avoir des indications très précises sur les osides contenus dans une plante. Désormais plus de recherches stériles, plus de travaux livrés au hasard dont les résultats sont souvent négatifs. Un simple examen préalable suffit à nous renseigner. De cette façon en 1921 on avait réussi à découvrir et isoler des hétérosides dans 56 espèces. Bourquelot lui-même extrayait 15 hétérosides nouveaux et sur la fin de sa vie, il disait avec justesse avoir tracé du travail pour des générations de chimistes et de physiologistes. De plus il réhabilitait nombre de plantes qui avaient été bannies de la pharmacopée un siècle auparavant, et il montrait que nombre de végétaux de la médecine populaire contenaient des principes actifs qui sont désormais inscrits au Codex.

A côté des résultats dont a bénéficiée la science pharmaceutique, il convient de signaler l'importance de la méthode dans l'étude de la constitution des osides.

Pour cela reportons-nous à un article de Bridel au sujet de l'étude par Bourquelot et Hérissey sur la constitution du gentianose. Ce dernier est

formé par l'union d'une molécule de fructose et de deux molécules de glucose.

Gentianose



Glucose Glucose Fructose

L'hydrolyse de ce composé peut être réalisée en deux temps par les acides suivant leur concentration. A la concentration de 2 pour 1000, il y a mise en liberté de fructose tandis que les deux molécules de glucose restent unies pour former du gentiobiose; avec une concentration de 30 pour 1000 le gentiobiose est hydrolysé en deux molécules de glucose. La même action peut être réalisée par l'invertine et l'émulsine: l'invertine met en liberté le fructose et l'émulsine les deux molécules de glucose. Si on arrive au même résultat final, il existe toutefois une différence dans la marche de l'opération. Ainsi, quelque soit la concentration de l'acide, on ne peut jamais arriver à hydrolyser le gentianose en mettant d'abord en liberté le glucose, c'est toujours le fructose qui est libéré le premier. On ne peut donc pas avoir une idée sur le mode d'union du glucose et du fructose dans le gentianose.

Avec les ferments tout est différent. Bridel et Bourquelot ont montré que par action de l'émulsine sur le gentianose., il y a libération d'une molécule de glucose, et l'autre molécule de glucose reste unie au fructose de façon à donner du saccharose qui a été obtenu à l'état cristallisé. Les ferments permirent donc d'élucider la constitution du gentianose.

A la suite de l'impulsion donnée par Bourquelot aux méthodes biochimiques, l'utilisation des ferments comme réactifs de laboratoire se généralisa, et l'effort porta sur d'autres ferments.

Un élève de Bourquelot, Vintilesco employa la myrosine, ferment répandu chez les crucifères, comme agent d'hydrolyse des hétérosides sulfurés.

En 1926 Bridel et Charaux utilisèrent un produit extrait des graines de rhamnus, qu'ils appelèrent rhamnodiastase. On ne connaît pas exactement les ferments qui s'y trouvent contenus, mais on sait qu'elle agit d'une façon analogue à l'émulsine, en libérant une partie non-glucidique et un ose qui n'est pas du glucose β mais un diholoside (primevèrose, rutinose, vicianose) ou un triholoside (rhamninose, robinose).

Plus récemment Mlle Bourdouil en étudiant la poudre de pancréas a montré qu'il était possible de l'utiliser pour la recherche du maltose, car on sait que le suc pancréatique contient de la maltase. Il faut remarquer que cette poudre agit aussi sur d'autres principes grâce à une amylase, une lipase et une protéase.

Enfin la méthode biochimique a permis la synthèse de plusieurs corps. Ce problème avait déjà été entrevu par Croft Hill, qui en mettant une macération de levure en présence d'une solution concentrée de glucose réussit la transformation d'environ 16% de glucose en disaccharides. Bourquelot et Bridel apportèrent des preuves incontestables de la réversibilité des réactions dues aux diastases. Grâce à l'émulsine dont la résistance à l'alcool est assez prononcée, ils réussirent à opérer la synthèse de toute une série de β glucosides. Ils ont montré que c'était la même diastase qui était capable de provoquer la réaction d'hydrolyse et la réaction de deshydratation. On a ainsi réussi à faire du gentiobiose et du cellobiose par action de l'émulsine sur le glucose; de son côté la maltase a fourni des β glucosides.

Cet exposé a montré tout le parti qu'il avait été possible de tirer des méthodes biochimiques et l'étendu des problèmes qui ont pu être posés. Avec une méthode aussi simple, il serait intéressant d'étudier les osides de nombre de plantes qui s'apparentent assez étroitement à certaines espèces européennes. Et même si l'on y rencontrait des principes actifs identiques, est-ce que ceux-ci s'y trouvent dans des proportions semblables, malgré la marche plus rapide de la végétation? D'autre part pour une même plante vivant sous des climats différents une étude sur le métabolisme des glucides, suivant les différentes saisons, serait du plus haut intérêt. Il est à souhaiter que de jeunes chimistes agronomes se lancent dans cette voie, car le sujet a été encore à peine abordé au pays.

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Etant donné la très nombreuse littérature se rapportant à la question, nous n'avons cité ici que les ouvrages concernant strictement le sujet traité.

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